Food and Agriculture Organization of the United Nations

Grazing with trees

A silvopastoral approach to managing and restoring drylands

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A silvopastoral approach to managing and restoring drylands

by
Fidaa F. Haddad, Pedro M.Herrera and Badi Besbes

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Cover photograph: A Karamojong pastoralist man takes his goat cattle to graze next to the village of Kochunoi, Uganda ©FAO/Luis Tato

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Foreword

Drylands constitute almost 48 percent of the world's surface – including presumed dryland areas – and are particularly vulnerable to climate change and climatic risks. Yet at the same time, population growth and global changes mean that an increasing number of people depend upon drylands for their livelihoods. These people are often accused of degrading land, overgrazing and cutting down trees and, as a result, eviction and marginalization are becoming increasingly frequent.

Investing in integrated land-use planning and management, including for dryland forests, is a worthwhile endeavour, and agroecological principles – based on science and traditional knowledge – can both lead to better livelihoods and restore ecological services. Solutions for restoring drylands while also supporting people's livelihoods come from traditional agroforestry systems that have been used for millennia, frequently combining the extraction of forest products with multispecies livestock production and small-scale agriculture – all of which are powerful livelihood providers.

Halting deforestation is crucial for supporting human livelihoods, as land populated with trees provides support for local communities exposed to poverty. Land-based livestock farming, specifically pastoralism, is considered a key activity for food security, sustainable development and resilience in drylands. Grazing livestock benefits forests, trees and silvopastoral landscapes by providing, regulating and supporting ecosystem services, such as seed dispersal, fertile and productive soils that sequester carbon and increase biodiversity, while preventing wildfires, avalanches and bush encroachment. Additionally, livestock benefit from the extra food sources and shelter provided by forests and trees. Consequently, silvopastoralism has gained importance in projects of the Food and Agriculture Organization of the United Nations (FAO), generating useful knowledge over time.

However, the delicate intricacies of the multifunctionality, circularity and sustainability of silvopastoral management are poorly understood outside their communities of practice, and researchers are only now coming to appreciate the concept with regard to sustainable development. In light of this situation, "Grazing with Trees" is a timely report which draws evidence from research, shares experiences from various case studies, and collates valuable knowledge from people on the ground. The report constitutes a solid foundation based on which we can analyse the current situation, discuss the main challenges and threats and, above all, build a roadmap to enhance the benefits provided by dryland silvopastoralism.

This paper builds on previous actions taken by FAO over the years to ensure sustainable agriculture, forest management and agroforestry systems are at the forefront of preserving land while safeguarding local livelihoods. This report will guide future actions in the field and clarify existing doubts about dryland silvopastoralism.

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Case study	Authors
The "*fundos de pasto*" agrosilvopastoral system	Jardel Luís Félix Pacheco and Anderson de Moura Bonilha, with the collaboration of Gustavo Stancioli Campos de Pinho, Marcello Broggio, Tiago de Carvalho, and Franca Rocha, FAO-Brazil.
A dryland cattle corridor as a resilience option for communities and a restoration option in South Sudan	Kenyi Bullen Baggu, Ministry of Environment and Forestry, South Sudan Juba.
Livestock grazing management regimes in dryland forests and silvopastoral systems in Kenya	Albert Luvanda, Clément Ngoriareng and R Tiwae, Kenya Forestry Research Institute, Dryland Eco Region Research Programme, Kenya Forest Service.
The summering–wintering practice in managing the Southern Andes dryland forest and mountains in Chile	Carla Marchant Santiago, Institute of Environmental and Evolutionary Sciences, Laboratory of Territorial Studies LabT UACh. Austral University of Chile and José Romero Cheuquepil Werken, Pedro Currilem Community, Pewenco Bajo, Lonquimay.
Financial performance of silvopastoral systems in Queensland, Australia	Tyron Venn, Tom Lewis, and Nahuel Pachas, School of Agriculture and Food Sciences, University of Queensland.
Sustainable silvopastoral restoration to promote ecosystem services in Tunisia	Mounir Louhaichi and Jamel Kailene, with the collaboration of Slim Slim, Bechir Tarchi, Mouldi Gamoun, Sawsan Hassan and Barbara Rischkowsky, ICARDA-Jordan, DGF-Tunisia, ESAM-Tunisia, CES/CRDA Zaghouan-Tunisia, ICARDA-Jordan,Ethiopia.

Case study	Authors
Silvopastoral systems and sustainability of Sahelian socioecosystems in Senegal	Alexandre Ickowicz, El Hadji Traore, Assouma Habibou, Paulo Salgado, Abdrahmane Wane, Ibra Touré, Simon Taugourdeau, Christian, Corniaux Tamsir Mbaye, Jean-Daniel Cesaro, Etienne Delay, Amy Bakhoum Morgane Dendoncker and Caroline Vincke, Cirad, France, ISRA, Senegal, Cirad-Cirdes Burkina Faso, Cirad-ISRA, Senegal, Cirad-ILRI, Côte d'Ivoire, UCAD, Senegal, Université Catholique de Louvain, Belgium.
Forest owners and livestock farmers determine the success of silvopastoralism in northeastern Spain	Elsa Varela, Ana Olaizola, Marc Taüll and Antonio Lecegui, Forest Science and Technology Centre of Catalonia (CTFC), University of Zaragoza, Catalan Institute of Agrifood Research and Technology.
Rangeland forests and silvopastoralism in Uzbekistan's cold deserts	Nariman Nishanov, FAO, National Coordinator of the CADI project in Uzbekistan.
Rational grazing on bocage perimeter in Burkina Faso	Aubin Ouedraogo, Seydou Kabore and Henri Girard, Terre Verte.
Conserve native flora through ecological restoration in the Royal Botanic Garden of Jordan	Mustafa Al-Shudiefat and Hana Kambay, The Royal Botanic Garden of Jordan.
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Community movements for ecosystem and livelihood resilience in Iran	Mina Esteghamat, Siavash Aghakhani, Amir Zand and Mahmoud Moradi, Center for Conservation and Development of Sustainable Ecosystems (ZIPAK NGO).
Traditional agrosilvopastoral system in Meridional Espinhaço range (Minas Gerais State/Brazil)	Fernanda Testa and Claudenir Fávero, Monteiro São Paulo University, Federal University of Jequitinhonha and Mucuri Valleys.
Participatory rangeland management-an enabling process for improving silvopastoral management and governance	Fiona Flintan, CGIAR Livestock, Climate and System Resilience initiative, International Livestock Research Institute (ILRI).
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Acronyms and abbreviations

ASAL	arid and semiarid lands
ASF	animal source foods
AUD	Australian Dollar
BAU	business as usual
BRL	Brazilian Real
CADI	Central Asia Desert Initiative
CaSSECS	carbon sequestration and greenhouse gas emissions in (agro) silvopastoral ecosystems in the Sahelian CILSS States
CBO	community-based organizations
CBRR	Community-Based Rangeland Rehabilitation programme
CEL	ecological local knowledge
CGIAR	Consultative Group on International Agricultural Research
CILSS	Permanent Interstate Committee for Drought control in the Sahel
CIRAD	The French Agricultural Research Centre for International Development
CN30	Carbon Neutral 2030
CO2	carbon dioxide
COFO WG	Committee of Forestry Working Group
CONAF	National Forestry Corporation
CSO	civil society organization
DGF	Directorate-General of Forests
ES	ecosystem services
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GEF	Global Environment Facility
GGW	Great Green Wall for the Sahara and Sahel initiative
GHG(e)	greenhouse gas (emissions)
GPS	Global Positioning System
ICCA	Indigenous Peoples' and Community-conserved Areas and Territories
ILRI	International Livestock Research Institute
INGREF	National Institute for Research in Rural Engineering, Water and Forests
IRPAA	The Regional Institute for Appropriate Small Farming and Animal Husbandry
IRTA	Institute of Agrifood Research and Technology
IUCN	International Union for the Conservation of Nature
LDN	land degradation neutrality
MLA	Meat and Livestock Australia

NE	northeast
NGO	non- governmental organization
NPA	Norwegian People's Aid
NPV	net present value
NTFP	non-timber forest products
PRM	participatory rangeland management
RBG	Royal Botanic Garden (Jordan)
SAFA	sustainability assessment of food and agriculture systems
SAGA	strengthening agricultural adaptation
SDG	Sustainable Development Goals
SLM	sustainable land management
SMP	silvopastoral management practices
SOC	soil organic carbon
SOM	soil organic matter
SPS	silvopastoral systems
SWOT	strengths, weaknesses, opportunities and threats
TASF	terrestrial animal source food
TND	Tunisian Dinar
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention of Climate Change
USD	United States Dollars

Main concepts and definitions used in this report

Silvopastoralism is a form of agroforestry that combines grazing livestock with forestry, benefiting from the ecological relationships between animals and woody plants (Plieninger and Huntsinger, 2018; Mosquera-Losada, Rigueiro and McAdam, 2005)

Accordingly, a **silvopastoral system (SPS)** is a silvopastoral production unit, that is an agricultural unit that integrates woody vegetation (trees and/or shrubs) with grazing animal production (Peri, Dube and Varella, 2016). For the purpose of this report, any production unit that integrates woody vegetation and grazing livestock is considered a SPS.

Other key concepts referred to in this report include:

- **Agroforestry** is the interaction of agriculture and trees, including the agricultural use of trees. This includes trees on farms and in agricultural landscapes, farming in forests and along forest margins, tree-crop production, silvopastoralism and agrosilvopastoralism (Grebner and Boston, 2022).
- **Agrosilvopastoralism** is a form of agroforestry that integrates trees with grazing animal production and crops, including woody crops and/or herbaceous crops (Pardini and Nori, 2011).
- **Forest grazing** is the use of any forest or tree plantation as a direct source of livestock feed. Traditionally considered just as a historical tool but more recently as a land management tool and a part of multifunctional SPS (Varga, 2017).
- **Intensive silvopastoral system** (ISPS) is an SPS that combines high-density cultivation of fodder shrubs with improved grasses, densified tree species or palms and grazing livestock (Grebner and Boston, 2022).
- **Modern silvopastoral system** (also **delimited** SPS, **improved** SPS or **designed** SPS,) is a design-based purposeful combination of trees, shrubs and grazing livestock in a single agricultural unit or SPS.
- **Native-forest silvopastoral system** (also natural forest silvopasture) is any SPS with pastures growing in combination with trees that are remnants from previous forest (Montagnini, Ibrahim and Murgueitio, 2013). This report also considers native-forest SPS based on extensive local and native species of trees, shrubs and grasses (Cubbage *et al*., 2012; Peri *et al*., 2016).
- **Silvopasture** is a synonym of silvopastoralism, especially in the United States of America and related areas (Smith *et al*., 2022). Also, the forest land supporting grazing.
- **Traditional silvopastoral system** (also "ancient SPS") is any silvopastoral production historically established in a given territory (Sales-Baptista and Ferraz-de-Oliveira, 2021), including their remnants and current expressions.

Executive summary

As the planet's population continues to increase, global demand for food, including terrestrial animal source food (TASF), is also forecast to increase by 1.4 percent per year over the next decade (OECD and FAO, 2022). Demand for timber and other forest products will also increase (FAO, 2017). To cope with the increased demand, it is expected that forests and pasturelands will be reduced to make way for cropland (Bahar *et al.*, 2020). FAO has modeled different scenarios to assess this demand growth under more significant resource constraints (FAO, 2018b). Moreover, some conservation and rewilding approaches fail to consider the role of local populations in nature conservation and neglect the socioeconomic context, banning grazing and further decreasing local access to land (Perino *et al.*, 2019). As available land decreases, sourcing and securing TASF and timber products from sustainable production systems is increasingly important (Bahar *et al.*, 2020). In terms of economic context, the value of a hectare of pastureland with trees currently varies between USD 500 and 1 000 per year depending on the rainfall regime and contextual variation of land prices.

Trees in dryland forests and wooded areas provide essential ecosystem services such as animal feed, timber, fruits, shade and regulation of soil and water cycles. They are vital for biodiversity and cultural services, linking people and trees (FAO, 2019). To illustrate this connection, early works state that about 15 percent of animal feed in the Sahel depends on trees, with this figure rising at least to 20 percent in both the Sahel and the Sudanese area during the dry season and potentially reaching 30 percent (LeHouerou, 1980). Additional feed sources including by-products and shrub leaves can also be integrated in silvopastoral systems (Amole *et al.*, 2022). Besides, people also use non-timber forest products for food and trade, and dead wood for energy.

Equally, the presence of livestock in dryland areas also delivers key services. Livestock is not only a source of income and high-quality nutrient-dense food, but also removes vegetation, including dry and flammable plants, and mobilizes stored biomass through depositions, which is partly transferred to the soil, improving fertility. Livestock is key to creating and maintaining specific habitats and green infrastructures, providing resources for other species and dispersing seeds (Tittonell *et al.*, 2021). Livestock production, in particular pastoralism, is considered a key activity for food security, sustainable development and resilience in drylands. When both elements – livestock and trees – are combined, it results in a complementarity of agroforestry systems that can boost the local ecosystem, representing a positive transition towards an integrated perspective of livestock and forest production. Trees offer feed sources with high nutritional value that can increase productivity, especially milk production. Landscaping options using

trees can also create shade for livestock and provide protection in harsh weather conditions, which is a powerful strategy for adapting to climate change.

The findings of this assessment confirm the importance of agroforestry, especially silvopastoralism, as a primary pathway for forest restoration in dryland areas, as recommended by FAO (2022a). FAO has developed many agroforestry field projects in drylands, accumulating extensive knowledge on the subject. Findings from dryland regions that have introduced trees to their agropastoral systems show impressive results. For example, microclimate measurements show lower soil temperatures in pastures with trees (between 2.2 and 2.3 degrees at 5 cm from the surface). In Latin America, pasture-based cattle farms increased their forage production by over 175 percent and their milk production per hectare by over 75 percent after incorporating trees into the local environment. In India, the Jhansi dryland areas increased their production tenfold using a 10-year rotation silvopastoral plan. In Senegal, hundreds of villages have been protecting their common grazing lands over the last 30 years, transforming degraded shrubs into savannah landscapes and increasing woody cover by up to 65 percent.

The paper offers a thorough assessment of the positive role that optimized extensive livestock grazing can play in the management and restoration of dryland forests and lands with trees. It provides sound evidence of the benefits of applying an integrated landscape approach and utilizing farmers' and pastoralists' knowledge to halt desertification, increase resilience and enhance food security against an ever-changing background.

The methodological approach adopted in the assessment reflects the innovative multidisciplinary expertise of both forest and animal science disciplines, building upon the work and lessons learned from practitioners and field experts linked to specific case studies across dryland regions. The methodological approach is based on four stages: i) knowledge assessment and literature review; ii) expert and stakeholder consultation at different levels to assess current knowledge and potential benefits and means of verification of this approach; iii) participatory analysis of field projects and initiatives to provide the assessment with case studies; and iv) expert discussions and consultations to collect evidence on the subject and formulate a roadmap for enhancing silvopastoralism in dryland forests.

The paper constructs a new narrative around the relationship between forests and livestock in drylands. It explores innovations in the relationship between forests and livestock, with a view to improving positive interconnections and compiling best practices and the wide-ranging social, economic and ecological benefits of silvopastoralism. It also examines challenges and knowledge gaps, especially those linked to specific dryland features, such as improving biomass cycles, achieving land degradation neutrality, optimizing water cycle management, improving soil properties and addressing climate change impacts in drylands. Finally, it sets out a framework to provide multilevel guidance that helps transition toward this integrative model.

The paper's path encourages landscape planners and decision-makers to consider livestock as allies, not enemies, and accelerate action to promote

healthy silvopastoral and agrosilvopastoral ecosystems while restoring tree cover. The insights and guidance from this assessment are a key contribution to the International Year of Rangeland and Pastoralists scheduled for 2026. The UN-designated year will encourage everyone to join efforts towards dryland restoration through many of the pathways highlighted in this report, including the development of longer-term policies aimed at creating sustainable and green jobs in dryland areas; empowerment of local women, youth and Indigenous Peoples to take a leading role in land restoration initiatives; and awareness raising on the role of sustainable forestry in achieving both economic and environmental goals.

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Chapter 1: Framing the baseline: land-use trees and livestock in drylands

Building sustainable food systems remains an essential solution to face a critical challenge for global development sustainability, according to the Statement of Action on the UN Food Systems Summit 2021: to feed a growing global population while protecting our planet. Although the 2020 Forest Resource Assessment survey confirms a slowdown in global deforestation, dryland forests in Africa recorded the second-highest level of deforestation in the period 2000–2018 with 49 Mha cleared, after South America with 68 Mha cleared. Cropland expansion (including oil palm plantations) is the main driver of deforestation, causing almost 50 percent of global deforestation, followed by livestock, accounting for 38.5 percent (Table 1). Livestock is a major source of greenhouse gas (GHG) emissions, accounting for nearly 14.5 percent of the total. However, grassland-based livestock systems are crucial for food security and livelihoods and support the resilience of almost 930 million poor Africans and South Asians in drylands.

There is a need to balance the benefits of terrestrial animal source foods and the livelihoods of livestock keepers and an equally urgent need to limit GHG emissions. By adopting best production and management practices, the livestock sector can reduce its environmental impacts and become more efficient in natural resource usage while ensuring food security. FAO estimates that improved management practices alone could reduce net emissions from livestock systems by about 30 percent (FAO, 2016). Halting deforestation and maintaining forests could avoid emitting 3.6 +/- 2 gigatons of carbon dioxide equivalent ($GtCO_2e$) per year between 2020 and 2050, including about 14 percent of what is needed before 2030 to keep planetary warming below 1.5 °C, while safeguarding more than half the Earth's terrestrial biodiversity (FAO, 2022a).

1.1 DRYLANDS: A PRIORITY AREA FOR ACTION

Moving above the 1.5°C warming scenario will lead to emerging threats in drylands. Between 1982 and 2015, 6 percent of the world's drylands experienced desertification driven by unsustainable land-use practices intensified by anthropogenic climate change. Despite an average global greening, anthropogenic climate change has degraded 12.6 percent (5.43 million km2) of drylands, contributing to desertification and affecting 213 million people, 93 percent of whom live in developing economies (Burrell, Evans and De Kauwe, 2020). Researchers have assessed the impact of 1.5 °C and 2 °C warming using transient

warming scenarios, finding that a warming of 1.6 C° over drylands could occur in a stabilized 1.5 °C warmer world by the end of this century, which would increase to 2.3 °C in drylands under a stabilized scenario of a 2 °C increase. The warming in drier regions is higher, and hyper-arid areas would experience even higher warming. Projected increase of precipitation will not be enough to offset the increased potential evapotranspiration (PET: 88.3–101.7 mm/year) over drylands, resulting in dryland expansion, with aggravated droughts leading to desertification and threatening livelihoods and the ecosystem (Wei *et al*., 2019).

TABLE 1
Trends and status of dryland forests at regional levels.

Regions	Status and trends
Northern Africa	Northern Africa is mostly threatened by land degradation and deforestation. The general drivers of degradation include urbanization, demographic changes, commerce globalization and agricultural expansion. Policies driving the sedentarization of nomadic and mobile pastoralists is causing overgrazing and land degradation in some areas of the region.
Western and Central Africa	These regions are mostly affected by climate variability and land-use change, disrupting the amount of water available to vegetation and boosting land degradation, particularly after the expansion of agricultural land and the loss of pastoral lands. Locally, overstocking and increased livestock production have reduced pasture productivity and soil fertility.
Eastern Africa	Eastern Africa has suffered severe degradation of dryland forests and woodlands with high losses of biological diversity and ecosystem services. The high rate of deforestation and degradation of dryland forests is driven by population growth, land-use change towards cropland, excessive harvesting of fuelwood and other products, wildfires, climate change and policy failure. Intensification of grazing livestock is also a cause of degradation and desertification, particularly around watering points and in valleys, driven by the shift in pastoralism from traditional to more market-oriented production systems. Conservation initiatives banning pastoralists are also reducing the availability of pastures, increasing pressure on dryland ecosystems.
Southern Africa	Southern Africa is also suffering from a decline of forest and woodland, but at a slower pace, with drivers that are similar to other African regions. Pastoralism is still practised, but large-scale industrial livestock farming has spread, causing major land degradation.
West Asia	In West Asia, changes in communal tenure, privatization and state control have disrupted pastoralist rights, generated conflicts with other users, and negatively impacted nomadic and transhumant activities. Some experiences reviving communal systems are being tested with promising results in improved governance. Urbanization, industrialization, intensification of agriculture and increased wildfires severely affect West Asian drylands.
Central and Eastern Asia	These regions are susceptible to climate change and environmental degradation, and conversion from grassland to cropland is one of the major trends in the area. Also, failure in policies oriented to settlement of nomadic pastoralists have increased degradation trends (Haddad *et al*., 2022) Desertification is a major issue in the region, with sandstorms having an increasing impact.
Southern Asia	Southern Asia is also experiencing conversion of land to agriculture, unsustainable exploitation of forest resources and inadequate policies. Climate change is also threatening southern Asian drylands by increasing risks of fire and invasive species, particularly in alpine areas. The growing population is also a major force in the region.

Regions	Status and trends
Oceania	Drylands in Oceania are also subject to desertification, wildfires, and shrub encroachment.
South America	Dry forests in South America are disappearing mainly because of intensive crop expansion and clearing for livestock production. Fuel crops, soy plantations and illegal logging are also having a direct negative impact.
North and Central America and the Caribbean	Drylands in these regions are also subject to degradation trends, with unsustainable grazing systems as the main cause, and increasing forest fires as one of the main threats.
Europe	Land degradation in drylands is a growing threat in the European Union, which is facing a scenario of increasing temperatures and droughts and less precipitation. The risk is especially high in the southern parts of Europe (ECA, 2018).

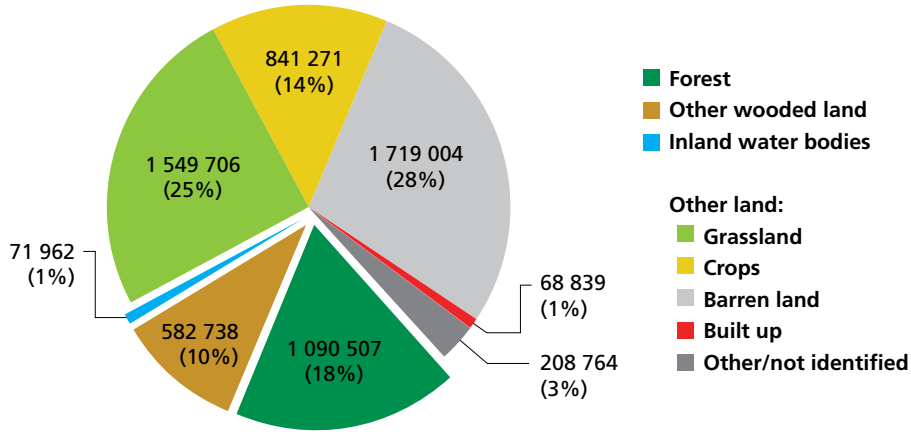
Source: **FAO.** 2019. *Trees, forests and land use in drylands: the first global assessment*-Full report. FAO Forestry Paper No. 184. Rome, FAO Forestry Paper. https://www.fao.org/documents/card/en/c/ca7148en/

Dryland forests account for 18 percent of the world's 6.1 billion hectares of drylands, compared with 25 percent for grassland and 14 percent for cropland. Crops, forestry and livestock are key economic assets in countries hosting large dryland surfaces in their territories (see annex 2).

Drylands are predominantly used as rangelands, including grasses (31 percent), other woody vegetation (covering up to 8 percent), shrubs, scattered trees, and barren lands. However, forests are key natural resources in drylands, accounting for 27 percent of the world's forest area concentrated in subhumid and semiarid lands. Crops account for 14 percent of drylands. (Figure 1)

According to the 2019 FAO report on *Trees, forests and land use in dryland: the first global assessment*, two-thirds of dryland forests have closed tree canopy, with a cover of more than 40 percent. Most of the trees in drylands are outside of forests. Almost 30 percent of cropland and 60 percent of land occupied by settlements and infrastructures have at least some tree cover. When forests, other wooded land and trees outside forests are all taken into account, trees are present on 2 billion hectares of drylands (32 percent of the total dryland area) (FAO, 2019).

FIGURE 1
Distribution of Land uses in dryland ('000 ha)

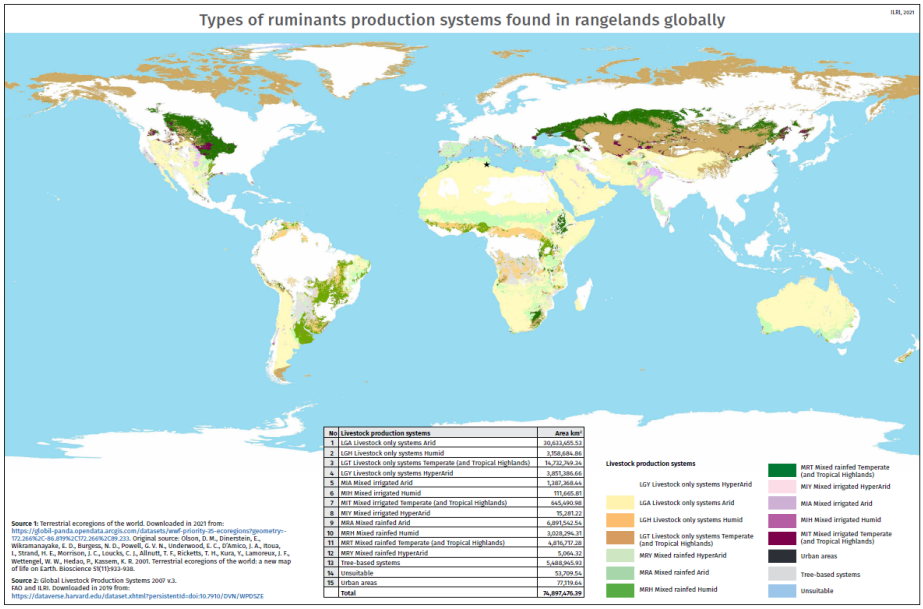


Source: FAO. 2019. *Trees, forests and land use in dryland: the first global assessment*-Full report. FAO Forestry Paper No. 184. Rome, FAO Forestry Paper. https://www.fao.org/documents/card/en/c/ca7148en/.

Livestock production is a widespread activity in drylands, although there are no specific censuses of the livestock thriving in these lands. Accurate grazing livestock data has proven elusive to extract for drylands or any other areas. Estimates suggest that drylands host half of the world's livestock (UNCCD, 2017), and livestock production is the main socioeconomic activity of many rural people in drylands. Rainfed agriculture is restricted in drylands, since crops are difficult to grow under those conditions, while timber production is slow and focused on the long-term. Grassland-based livestock production seems to be the only primary production reliable enough to cope with most dryland conditions and environmental variability, especially in the most arid lands. Its adaptability, built upon the mobility of animals and the decision-making capacity of their caretakers, is a known component of its resilience (FAO, 2018a). Pastoralism, considered in its broad sense as extensive livestock production based on rangelands and land resources (Davies *et al.*, 2016), is the only possible form of land use in many drylands (de Haan, 2016). Accordingly, dryland dwellers rely on it for food provision and income (Neely, Bunning and Wilkes, 2009).

A geographical approach to this use can be inferred from the Rangelands Atlas (ILRI *et al.*, 2021), specifically for the ruminant-based production systems. According to this source, ruminant production systems exclusively based on livestock occupy more than 70 percent of the world's drylands (especially in the arid lands), while an additional 7 percent of drylands host livestock systems based on trees. Besides, another 17 percent of the drylands host mixed systems with livestock feeding on croplands and crop sub-products (Figure 2). These data confirm that pastoralism is the most important productive activity in drylands and that the livelihoods of most dryland inhabitants depend on livestock production.

FIGURE 2:
Types of ruminant production systems found in rangelands globally according to the Rangeland Atlas


Types of ruminants production systems found in rangelands globally
ILRI, 2021
No Livestock production systems Area km²
1 LGA Livestock only systems Arid 20,631,655.53
2 LGH Livestock only systems Humid 3,158,684.86
3 LGT Livestock only systems Temperate (and Tropical Highlands) 14,722,749.24
4 LGY Livestock only systems HyperArid 3,851,386.64
5 MIA Mixed irrigated Arid 1,187,368.64
6 MIH Mixed irrigated Humid 111,665.81
7 MIT Mixed irrigated Temperate (and Tropical Highlands) 645,490.98
8 MIY Mixed irrigated HyperArid 15,281.22
9 MRA Mixed rainfed Arid 6,891,562.54
10 MRH Mixed rainfed Humid 3,028,294.31
11 MRT Mixed rainfed Temperate (and Tropical Highlands) 4,816,737.28
12 MRY Mixed rainfed HyperArid 5,064.22
13 Tree-based systems 5,488,945.93
14 Unsuitable 53,709.54
15 Urban areas 77,719.64
Total 74,897,476.39
Livestock production systems
LGY Livestock only systems HyperArid
LGA Livestock only systems Arid
LGH Livestock only systems Humid
LGT Livestock only systems Temperate (and Tropical Highlands)
MRY Mixed rainfed HyperArid
MRA Mixed rainfed Arid
MRH Mixed rainfed Humid
MRT Mixed rainfed Temperate (and Tropical Highlands)
MIY Mixed irrigated HyperArid
MIA Mixed irrigated Arid
MIH Mixed irrigated Humid
MIT Mixed irrigated Temperate (and Tropical Highlands)
Urban areas
Tree-based systems
Unsuitable
Source 1: Terrestrial ecoregions of the world. Downloaded in 2021 from:
https://global-panda.opendata.arcgis.com/datasets/wwf-priority-25-ecoregions?geometry=-172.266%2C-86.899%2C172.266%2C90.233. Original source: Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., Kassem, K. R. 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938.
Source 2: Global Livestock Production Systems 2007 v.3.
FAO and ILRI. Downloaded in 2019 from:
https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/WPDSZE

Source: ILRI, IUCN, FAO, WWF, UNEP & ILC. 2021. *Rangelands Atlas. Nairobi: ILRI*. www.rangelandsdata.org/atlas

1.2 MANAGING TREES IN DRYLANDS: DEFORESTATION, AFFORESTATION AND REFORESTATION

The restoration of trees remains among one of the most effective land-based strategies for climate change mitigation (Bastin *et al*., 2019), although not without risks and trade-offs that need to be addressed in a long-term strategy (Hermoso *et al*., 2021). Trees are important in drylands for food security, livelihoods, ecosystem services (ES) and land degradation neutrality (LDN) (FAO, 2019). Nevertheless, afforestation is not always the best solution, and neither are all kinds of trees, nor all types of land suitable for tree cover. Sometimes trees are the best alternative for an adaptation or sustainability strategy. Other times, other land-use types, such as grasslands and rangelands, could bear those functions more appropriately (Rojas-Briales, 2015). Warnings have been raised that drylands could be inappropriate ecosystems for tree cover overexpansion due to the risks of biodiversity loss, water overconsumption and fire (Fagan, 2020). On the other hand, grassland-based livestock management in lands with trees can contribute to management that simultaneously improves conditions for tree growth in selected and specific pastoral lands, while preventing wildfires and improving the provision of ES and adaptation to climate change (Herrera, 2020).

Wildfires are a growing global problem linked to climate change; they are widespread in rangelands, dry forests and other dryland ecosystems, and especially affect tropical and temperate areas. Some authors consider wildfires as

a major disturbance in rangelands, others see them as a key ecological factor with important ecosystem functions (Stavi, 2019). Wildfire impacts are site-specific and context-dependent. The unique characteristics of rangelands make them more resilient and better adapted to wildfires than dense forests, because of the vegetation structure and fuel distribution that lessen fire intensity and improve recovery capacity. Managing drylands, open forests and rangelands in a way that prevents the consequences and damage caused by wildfires depends mostly on grazing. Prescribed fires, clearings, vegetation removal and other methods can be applied to control fuel but eventually, all these systems need maintenance and proper management, which comes mainly from grazing and browsing. A combination of clearings and other vegetation control tools maintained with extensive livestock grazing offers good fire prevention results, although the structural causes of the problem must also be considered (Lasanta *et al*., 2018). Moreover, the local population is instrumental in the search for and implementation of integrated fire management solutions and must be actively involved in both the decision-making and operation of the solutions presented.

1.3 DEALING WITH WOODY VEGETATION, SHRUBS AND GRASSLAND IN GRAZED DRYLANDS

Woody plant colonization has coincided with the global intensification of livestock grazing, especially in developed countries. This phenomenon threatens the maintenance of dryland savannahs and rangelands, although a single interpretation of shrub encroachment as a form of degradation is not possible, and many outcomes ranging from desertification to ecosystem enhancement may occur (Eldridge *et al*., 2011). On the latter, several benefits have been described, from the increment of woody plants in rangelands to increased ES. The balance often depends on appropriate response management, retaining the ability of the landscape to produce fodder for livestock, while increasing the production of wood and tree-dependent products and services. Ultimately, maintaining open landscapes with vegetation within a desirable mix of herbaceous and woody plants is a key component of rangeland ecosystem management (Archer, 2010). It is also important for rural households that depend on the many benefits of forests (fuelwood and livestock production, but also fruits, herbs, honey, nutraceuticals, etc.) (Mirzabaev *et al*., 2019). The trade-offs between the level of encroachment, carbon stocks, biodiversity, fire risk, provision of water and pastoral value open the door to different silvopastoral approaches, managed with tools like clearing, burning, grazing, fencing, protecting, and so on (ibid.).

Shrub encroachment is linked to the abandonment of marginal areas and the intensification of livestock production in several parts of the world, increasing the combustible biomass levels and the risk and intensity of wildfires. Fuel reduction by herbivores, both grazers and browsers, is a promising management strategy to manage wildfire risk. However, its effectiveness depends on a range of factors, including herbivore type, population density and feeding patterns. In

general, herbivores reduce fuel load most effectively when they are mixed species herds, and when herbivore food preferences match the local vegetation. In some cases, the combination of herbivory with other management strategies, such as prescribed fires, mechanical clearing, improved accessibility and passing through water points, is necessary to reduce wildfire damage (Rouet-Leduc *et al.*, 2021). Those strategies also contribute to preventing land from being degraded.

The global increase of woody vegetation poses a singular challenge to a grazing-based management approach to forests and lands with trees in drylands. Further expanding woody cover constitutes a clear threat for grazed lands, reduces the quality and quantity of fodder plants, increases fire risks and indicates degradation processes, therefore requiring control measures. Conversely, careful management of shrubs can contribute to the productivity and performance of dryland rangelands, by providing additional fodder with extended availability (the foundation of fodder banks), shelter for new samplings and seedlings (and wildlife), natural fencing and borders and additional ES. Shrubs are a key element of the silvopastoral approach, and their management should be positively integrated into any development plan.

1.4 ASSESSMENT METHODOLOGY

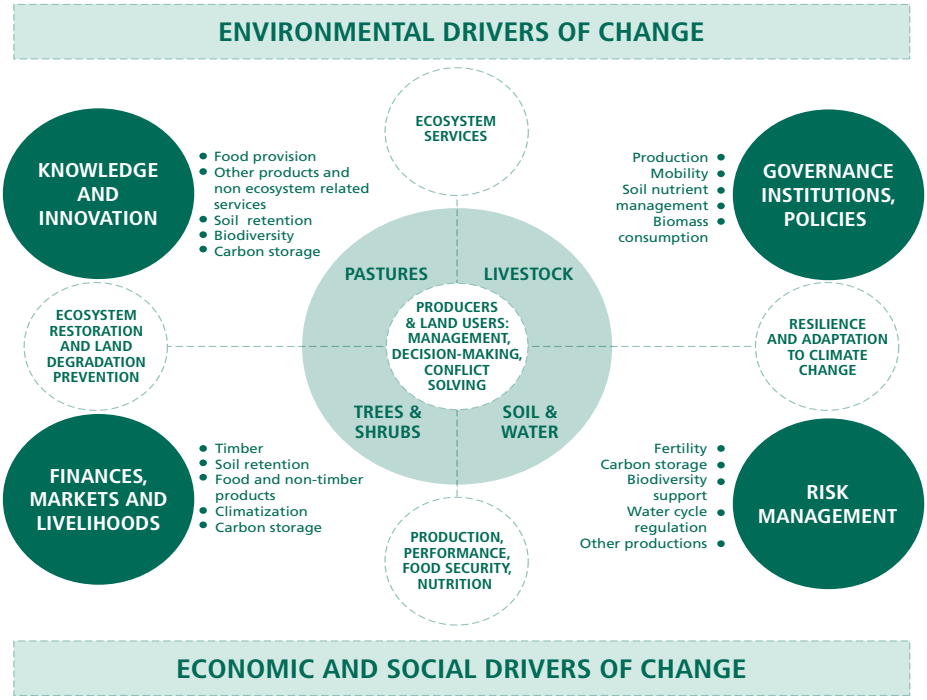
FAO recognizes the vulnerability of drylands and their contribution to global production systems. Drylands lie at the interface of the four sustainability domains, (social, economic, environmental and political), which in turn are aligned with the four betters (better production, better nutrition, better environment and better livelihoods) of FAO's Strategic Framework 2022–2031. This technical paper highlights the multiple contributions of forests, trees and livestock through a silvopastoral approach to sustainable agriculture and food systems, thereby enhancing FAO's cross-sectoral work. Silvopastoralism is a contributor to FAO's four betters and strategic action – responsible in terms of both the environment and production for multiple positive outcomes for both farmers and society (Yadav *et al.*, 2019) and one of the best strategies for livestock production based on local resources. Additionally, silvopastoralism increases adaptive capacity and decreases vulnerability to climate change (Solorio *et al.*, 2017). Several of those benefits are linked to the integration of trees and livestock and the enhanced role of trees in silvopastoral dynamics (Moreno and Rolo, 2019); while others are directly linked to improved landscape management and ES (Torres-Manso *et al.*, 2017). However, not all benefits will be possible in every silvopastoral system: it all depends on the design, management level, external circumstances and management objectives (Soni *et al.*, 2016).

FAO defines silvopastoralism as the deliberate integration of trees and livestock (FAO, 1991). The definition has been enhanced to consider silvopastoralism as a form of agroforestry that combines grazing livestock with forestry, benefiting from the ecological relationships between animals and woody plants (Plieninger and Huntsinger, 2018; Mosquera-Losada, Rigueiro and McAdam, 2005). This integrated approach could improve food production and security, provide income

to better the livelihoods of those who depend on livestock and trees, and enhance the ES that these lands provide, thus facilitating the restoration and management of lands with trees in arid and semiarid zones. Collaboration between grazing and forestry can combine economic performance with social advances and environmental benefits, generating sustainable outcomes (see definitions page 12).

Accordingly, a conceptual framework (Figure 3) was proposed and validated by the Committee on Forestry (COFO) Working Group on Dryland Forest and Agrosilvopastoral Systems in its second session, hosted by the Government of the United Republic of Tanzania and held virtually in November 2021. The conceptual framework, which aims at assessing the potential role of grazing livestock in restoring land and ecosystems in the world's drylands, especially in forests and trees outside forests, relies on four critical aspects of decision-making: institutions; knowledge and innovation; risk management; and finance and livelihoods, and takes all four into consideration, while attaching substantial importance to system analysis.

FIGURE 3
Conceptual framework of silvopastoral systems



Source: Elaborated by authors and the COFO WG

Performance analysis of grazing livestock systems through indicators has received wide attention in research, with extensive reviews focusing on drylands (Alary *et al.*, 2022), grassland restoration (Bardgett *et al.*, 2021) and forest restoration (Buckingham *et al.*, 2019). Moreover, Mitchell (2010) and Motta-Delgado *et al.* (2019) highlighted the importance of grazing livestock systems in sustainable management of forests and rangelands, the sustainability of pastures

and other related topics. Similar efforts have been made regarding addressing the relationship between silvopastoralism and biodiversity (Rois-Díaz, *et al.*, 2006), soil health (Ramakrishnan *et al.*, 2020) and other sustainability criteria. The difficulties of obtaining sound data (whether addressing land use in SPS or the lack of integration of forests and rangelands) have prevented the appearance of a standardized indicator-based assessment methodology of silvopastoral land management. However, some efforts have been made by researchers and project managers working specifically on economic assessment (Francis *et al.*, 2022), sustainability (Hanisch *et al.*, 2019), ES (Fagerholm *et al.*, 2016) and agroforestry approaches (Marinidou *et al.*, 2019).

This technical paper outlines four steps for collecting evidence from the ground on the contribution of silvopastoral management to sustainable grazing with trees in drylands, as well as the scientific and practical indicators for validating the conceptual framework proposed in this forestry paper.

Step 1: A preliminary review of the different projects and initiatives implemented by FAO and partners in dryland regions, in addition to the literature review, which included scientific peer-reviewed articles and grey literature (reports and other documents) on the topic of grazing with trees. This step contributed to building the list with its actual configuration of potential benefits, criteria and means of verification, summarizing this information and helping to build a consistent set of indicators (Table 2).

TABLE 2
The potential benefits of sillvopastoralism

Economics	Social	Environmental
Improved biomass production and circulation: increased dry matter production, nutritional energy and raw protein	Better job satisfaction	Improved ES: provision, regulation, support and cultural
Improved forage production and nutritional properties	Better opportunities for women	Increased biodiversity
Increased fodder resources	Better match with society's sensibility and ethics	Increased connectivity
Raised livestock production	Improved social perception of livestock production systems	Improved coexistence with wildlife
Increased productivity, performance and net returns	Increased overall land value	Improved habitats for pollinators and beneficial insects
Improved soil properties, nutrient retention and availability for plants	Increased resilience and adaptation capacity	Enhanced carbon storage and CC mitigation performance
Facilitated association with wild species		Prevents land-use change and fragmentation
Improved N-fixation		Prevents forest fires

Economics	Social	Environmental
Improved richness species and nutraceutical value		Increased soil fertility and quality
Improved animal welfare		Improved water balance and water cycle management
Increased value on the ES market		

Source: based on Moreno *et al.*, (2014); Soni *et al.*, (2016); Solorio *et al.*, (2017); Torres-Manso *et al.*, (2017); Yadav *et al.*, (2019); Chará *et al.*, (2019); and Moreno and Rolo, (2019).

Step 2: The COFO WG advisory committee analysed those findings, categorizing the key themes for arranging the selected case studies and projects, which geographically covered the different dryland regions, namely:

Theme 1: Multifunctionality of silvopastoral approach for improving the production, economics, nutrition and livelihoods of dryland communities.

Theme 2: Silvopastoralism's contribution to ecosystem health, restoration and provision of ES.

Theme 3: Silvopastoralism's contribution to climate change resilience and adaptation and improved governance.

Accordingly, the compilation of the potential benefits and outcomes obtained by each of these themes is planned through a systematic approach, focused on dryland forests and trees outside the forest and following a logical path, as described in Figure 4 and Table 3 below:

FIGURE 4
Framework for assessing the role of grazing in drylands with trees

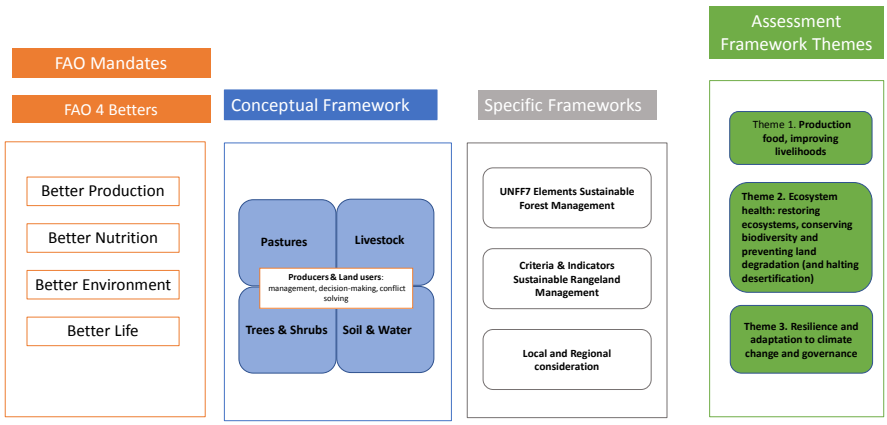

FAO Mandates
FAO 4 Betters
Better Production
Better Nutrition
Better Environment
Better Life
Conceptual Framework
Pastures
Livestock
Producers & Land users: management, decision-making, conflict solving
Trees & Shrubs
Soil & Water
Specific Frameworks
UNFF7 Elements Sustainable Forest Management
Criteria & Indicators Sustainable Rangeland Management
Local and Regional consideration
Assessment Framework Themes
Theme 1. Production food, improving livelihoods
Theme 2. Ecosystem health: restoring ecosystems, conserving biodiversity and preventing land degradation (and halting desertification)
Theme 3. Resilience and adaptation to climate change and governance

Figure 4: The diagram shows the process for designing a specific framework for this assessment, starting from FAO mandates and general framework (the four betters), through the conceptual framework included in the concept note and some specific approaches from forest and rangelands sustainable management. The original benefits were described by Soni et al., (2016); Moreno and Rolo, (2019); and Yadav et al., (2019) among others. The main criteria to organize those benefits relate to four comprehensive works on sustainable forest and rangeland management: Linser and O'Hara, (2017); United Nations, (2007); FAO, (2010); and Mitchell, (2010).

TABLE 3
Thematic focuses, potential benefits and proposed means of verification for addressing the potential benefits of dryland silvopastoral initiatives

Thematic focus	Potential benefits	Proposed verification sources
Theme I. Silvopastoralism is a multifunctional appraoch for improving production, economics, nutrition and livelihoods of dryland communities	Improved economic results	Economic balance, gross and net margins
	Reconciled trade-offs and improved synergies between forests and livestock	Amount of feed from woody sources to each species and breed of livestock
	Improved employment and opportunities for men and women	Average wage for men and women
	Improved social perception	Producer and stakeholder perceptions
	Improved food security and nutrition	Diet quality and nutritional value
Theme II: Silvopastoralism contributes to ecosystem health, restoration and provision of its services	Increased natural capital	Nodes, buffers and corridors managed by silvopastoralists
	Improved land use and planning	Practising traditional activities in forest areas
	Improved ES	Multifunctional landscapes
	Improved nature conservation	Inclusion of pastoralists in conservation programmes
	Increased surface and regeneration of drylands with trees	Presence of seedlings, sprouts and renewals
	Enhanced plant communities	Key species phenology, including pollenization-related issues
	Improved soil properties	Diversity and activity of soil microorganisms
	Control of erosion and soil degradation	Carbon stocks and fluxes
	Prevention of wildfires	Prevalence and frequency of forest fires managed by grazing
	Enhancing restoration plans and initiatives	Restoration, afforestation and reforestation projects with pastoralist presence
Theme III: Silvopastoralism contibutes to climate change resilience and adaptation and improved governance	Enhanced adaptation capacity	Distribution and orientation of vegetal barriers
	Increased resilience	Risk management tools used by pastoralists
	Improved equality and rights	Women occupying positions in decision-making institutions
	Improved governance	Presence of silvopastoralists and pastoralists in local institutions

Furthermore, the trade-offs and benefits were addressed based on the results of different case studies (activities and scenarios). However, it is important to

acknowledge that some of the potential benefits may not be delivered by all projects, and even that negative outcomes could arise in their place, usually linked to unwitting mismanagement (e.g. continuous grazing of livestock on land with trees can result in preventing natural regeneration). Table 4, adapted from Bardgett *et al.*, (2021), provides a set of indicators that have been useful in analysing potential means of verification of ES trade-offs and used in the discussion of case studies presented in this paper.

TABLE 4
Indicators and ecosystem structure and function parameters associated with ES in grasslands, adapted from Bardgett *et al.*, (2021).

Ecosystem services	Ecosystem structure/function	Common indicators
Forage production (quantity)	Annual above-ground biomass production	Net primary productivity Above-ground biomass
Forage production (quality)	Protein content and digestibility	Leaf N content Presence of species of nutritional importance
Forage reliability	Inter-annual variation in above-ground biomass production	Net primary productivity Species composition
Other grassland products (medicinal, food, hunting)	Species of particular interest	Species presence and/or abundance
Biofuels	Woody species of interest Grass species of particular interest (including flammable or high-yielding species)	Cover or biomass of species of interest
Species of cultural value	Presence of species of cultural interest	Species presence
Aesthetic value	Plant community composition and phenology	Flower diversity and colour and the presence of "unattractive" species Flowering phenology
Biodiversity conservation value	Plant and animal (vertebrate and invertebrate) species	Presence and abundance of species of conservation value
Regulation of invasive exotics and other undesired species	Invasive exotic species Species of negative pastoral or cultural value	Presence and abundance of undesired species
Global climate regulation	Carbon stocks and carbon cycling processes	Soil respiration and carbon stocks Woody species biomass and vegetation carbon stocks Litter mass and depth

Ecosystem services	Ecosystem structure/function	Common indicators
Maintenance of soil fertility	Nutrient stocks and nutrient cycling processes	Soil nutrient and carbon content Litter mass Soil enzyme activities
Maintenance of soil stability and regulation of erosion	Soil stability in the root profile Erosive flows	Evidence for erosion, bare ground cover and soil organic matter (SOM) and measures of soil loss and erosive flows Soil aggregate stability, bulk density and water holding capacity Plant rooting profile
Regulation of hydrological flows	Soil water retention and flows	Soil texture and bulk density and SOM content Soil electrical and hydraulic conductivity
Regulation of water quality	Retention and transformation of pollutants in soil	Soil properties include texture, pH, cation exchange capacity, salinity and water table depth SOM content and available water capacity Nutrient and pollutant concentrations in freshwater bodies

Step 3: An online survey was conducted to target the field staff and practitioners with different experiences in agroforestry, forestry, livestock management and silvopastoralism. The survey aimed to evaluate the soundness of the different criteria, the relevance of the proposed indicators and the availability of data in different projects to support the development of this assessment. This step thus helped put together a prioritized list with the most suitable items for the assessment.

The survey results confirmed the prioritization of the three themes agreed by the advisory committee. Annex 1 shows the survey results, including the list of criteria, benefits and means of verification that have been proposed to compile a list of codes in order to qualitatively analyse the contents of each case study, while also addressing the thematic and global approach and thus assessing the priorities and key outcomes. The quantitative coding system was based on the value of the perceived positive effects of SPS in dryland forests and lands with trees.

Furthermore, participants in the survey proposed other criteria and means of verification that should be considered when assessing the outcomes of silvopastoral initiatives. These additional criteria include quantifying the diversification of silvopastoral production, tax payments, investments in silvopastoral activities, improved data on the markets and value chains of silvopastoral products, employment and daily food expenses to assess potential benefits for diets and nutrition. Regarding ES and natural capital, the focus includes:

- knowledge and training of local stakeholders and technical support on biodiversity;
- monitoring the evolution and regeneration of local landscapes;
- addressing land capability and suitability classes;
- applying zonation to land, tracking soil carbon storage;
- using IUCN red lists for assessing the links with endangered species; and
- applying ecosystem-based criteria to assessing the outcomes of an approach based on grazing with trees and silvopastoralism.

Additional recommendations on forest regeneration and ecosystem restoration highlighted the role of species dispersion and regeneration, the use of erosion control infrastructures, and the evolution of seedlings and other restoration initiatives, with special consideration of the role of women and local communities to support the diversification and coexistence of different activities.

Step 4: Analysis of the outcomes reported by the case studies was developed by linking the case studies with the list of criteria and potential outcomes. The frequency with which each of those benefits was cited in the different case studies was assessed, evaluating the importance that the different items received regarding their presence and relevance in the case studies. This analysis was achieved by coding the case studies using Atlas.Ti software and its graphic display tools to show the links between the case studies and the criteria listed.

Seventeen case studies from 14 dryland countries were selected and assigned to one of the proposed three themes based on their primary focus and aims, thus ensuring the balance between themes and case studies. Table 5 shows the geographical distribution of the case studies with further details of their initiatives and projects.

TABLE 5
The distribution of case studies by theme-country landscapes.

Group	Number	Case title	Country
Theme 1: Multifunctionality of silvopastoral approaches for improving production, economics, nutrition and livelihoods of dryland communities	1	The "*fundos de pasto*" agrosilvopastoral system	Brazil
	2	A dryland cattle corridor as a resilience option for communities and a restoration option in South Sudan	South Sudan
	3	Livestock grazing management regimes in dryland forests and silvopastoral systems in Kenya	Kenya
	4	The summering–wintering practice in managing the Southern Andes dryland forests and mountains in Chile	Chile
	5	Financial performance of silvopastoral systems in Queensland, Australia	Australia

Group	Number	Case title	Country
Theme 2 Ecosystem health: biodiversity, ES, restoration	6	Sustainable silvopastoral restoration to promote ES in Tunisia	Tunisia
	7	Silvopastoral systems and sustainability of Sahelian socioecosystems in Senegal	Senegal
	8	Forest owners and livestock farmers determining the success of silvopastoralism in northeastern Spain	Spain
	9	Rangeland forests and silvopastoralism in Uzbekistan's cold deserts	Uzbekistan
	10	Rational grazing on bocage perimeter in Burkina Faso	Burkina Faso
	11	Conserving native flora through ecological restoration in the Royal Botanic Garden of Jordan	Jordan
Theme 3: Resilience, adaptation to climate change and governance	12	Characterizing grazing livestock systems for tailored adaptation support in Fatick, Senegal	Senegal
	13	Community movements for ecosystem and livelihood resilience in Iran	Islamic Republic of Iran
	14	Traditional agrosilvopastoral systems in meridional Espinhaço range (Minas Gerais State/Brazil)	Brazil
	15	Participatory rangeland management – an enabling process for improving silvopastoral management and governance	West African countries
	16	Updates on legal silvopastoralism instruments in Lebanon	Lebanon
	17	Silvopastoral strategy for Morocco	Morocco

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Chapter 2: Building common ground for evidence-based silvopastoralism in dryland forests

The United Nations General Assembly proclaimed 2021–2030 to be the United Nations Decade on Ecosystem Restoration with the primary vision to restore the relationship between humans and nature. Several studies and campaigns have called for tree planting to achieve the targeted commitments before 2030. According to a study by the Swiss Federal Institute of Technology in Zurich, an additional 0.9 billion hectares of the Earth's surface could support forests and woodlands, which if allowed to grow to maturity, could store approximately 205 gigatons of carbon.

In drylands, SPS are the most common and extended agroforestry systems, with multiple combinations of management systems, practices and outcomes (ILRI *et al*., 2021). Despite differences in structure, the composition of trees, shrubs, grasses and livestock, geographical locations and typologies, the interactive dynamics among silvopastoral components are equally important in characterizing those systems. When local knowledge of land uses is considered, silvopastoralism emerges as the approach that best represents the intricacies of dryland agroforestry. In all of them, the vegetal elements (grasses and herbs, shrubs, trees) are integrated into the same unit of production and land management to increase the period of fodder availability and improve productivity and adaptation.

2.1 GRAZING WITH TREES: THE BACKSTORY

It is thought that herders and livestock producers began using forests and lands with trees as key features of their production systems from the very moment they started to herd livestock (José and Dollinger, 2019). Forest grazing is a traditional activity around the world (Sharrow, 1997), from Bhutan (Norbu, 2002) and Japan, where it dates back to the thirteenth century (Adams, 1975) to the Mediterranean region and Europe (Adams, 1975).

Early twentieth-century research on US National Forests shows a growing interest in the use of grazing in forest management, as a way to revegetate and improve the land (Korstian, 1921). These early works already considered rotational grazing after seed maturity to favour progressive succession, even in degraded forests and rangelands, and also the prevention of wildfires. Conversely, continuous grazing is considered to degenerate tree cover, destroy the vegetation and impair the fertility of the soil through erosion.

Two different, almost contradictory visions have emerged around forest grazing. On the one hand, the European perception of forest grazing is that it is a damaging activity, harming trees and destroying samplings, compacting soils, reducing water infiltration and degrading the herbaceous vegetation by overgrazing. Livestock has been considered an enemy of the forest and classified among key degradation factors (Kissinger, Herold and Sy, 2012; Thompson *et al*., 2013). The negative vision of forest grazing has been often centred, though not exclusively, on the Mediterranean, where "uncontrolled grazing" was seen as highly undesirable and held responsible for the degradation of Mediterranean forests, neglecting the fact that some of the most successful silvopastoral approaches also originate from the Mediterranean, in response to their particular climatic conditions (Pinto-Correia *et al*., 2021).

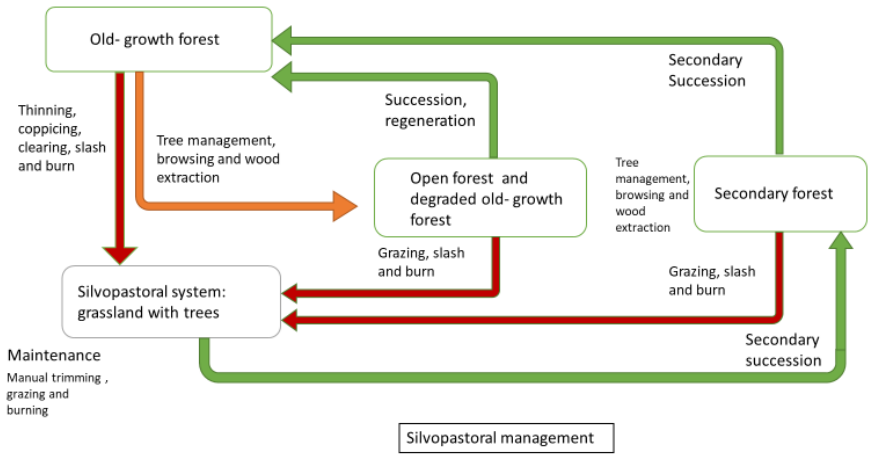
On the other hand, the perception in the United States of America, represented by national forest policy, was that the protection and development of forest wildlife must go hand in hand with the development and management of the range of resources for use by livestock (Korstian, 1921). Accordingly, timber production and controlled grazing were deemed compatible in forest areas and supported by the United States Department of Agriculture Forest Service (Sharrow, 1997), including grazing planning systems and detailed instructions to make silvopasture a desirable activity in the forest (Hamilton, 2008). Moreover, in theory, forest grazing was supposed to increase the efficiency of forest production, although the conversion of this theory into successful practice has created a challenge for the future.

2.2 AGROFORESTRY MEETS DRYLAND NEEDS

SPS are the most common and extended agroforestry systems in the world, with multiple combinations of management systems, practices and outcomes (ILRI *et al*., 2021). The experience gained in tropical SPS may prove useful for temperate areas and drylands. Thus, a further integrative approach to understanding the vulnerabilities and enhancing the resilience of extensive livestock grazing is a common goal in conserving and improving SPS worldwide. (Sales-Baptista and Ferraz-de-Oliveira, 2021).

Improved grazing management could fight degradation and improve conservation and restoration values (Röhrig, Hassler and Roesler, 2020), although this consideration has often been underacknowledged, neglecting grazing's constructive potential. Forest grazing as a strategy of land management is currently endorsed and promoted by forest institutions and agroecological promoters in different parts of the world According to Gabriel, (2018), Mercker and Smith, (2019), and Herden and Paulo, (2020) as shown in Figure 5, the challenge is to develop this approach in drylands at a global scale, considering not only their particular conditions but also the specificities of the structure and dynamics of their forests and trees.

FIGURE 5
Conceptual model of transitioning stages of forests under silvopastoral management



Source: Adapted from Sánchez-Romero, R., Balvanera, P., Castillo, A., Mora, F., García-Barrios, L. E. & González-Esquivel, C. E. 2021. Management strategies, silvopastoral practices and socioecological drivers in traditional livestock systems in tropical dry forests: An integrated analysis. Forest Ecology and Management. Elsevier B.V., 479, p. 118506. doi: 10.1016/j.foreco.2020.118506)

2.3 MAPPING SILVOPASTORALISM FOR DRYLAND FOREST AND TREES

Livestock used in silvopastoralism includes ruminants (for example: sheep, goats, cattle, yaks, water buffaloes), camelids, horses, donkeys, pigs and poultry. Silvopastoral livestock are mobile and can be fed directly with a wide range of biomass (both wild and cultivated) that is generally not edible by humans (ILRI et al., 2021).

Silvopastoralism integrates different systems, functions and processes at each territorial level, generating rights and governance frameworks of access and use of natural resources. It also facilitates flexible frameworks involving cohabitation with other land uses, such as woodlands or crops, as well as other pastoral systems (e.g. nomadic) and forests (Davies *et al.*, 2016). Trees and livestock establish different relationships in different areas and under different management systems.

In South America, where cataloguing and systematizing SPS is most advanced, a comprehensive approach is used (Peri, Dube and Costa Varella, 2016). There the focus is often on intensive SPS with simplified structures. Those intensive SPS are mostly cattle-oriented, which demand seed investments and land preparation and are more suited for tropical and humid temperate environments (Braun, Van Dijk and Grulke, 2016), although they have also been implemented in dryland regions such as El Chaco in Argentina (Baldassini *et al.*, 2018), where the results remain inconclusive.

Traditional silvopastoralism has been less studied in the dry regions of Latin America (Grünwaldt *et al*., 2016) and its importance has frequently been overlooked, although there are remarkable examples of traditional dryland silvopastoralism, such as the Brazilian Caívas (Hanisch *et al*., 2019) in the Cerrado or Caatinga region (Pinheiro and Nair, 2018), in Southern Mexico (Cancino, Nahed and Velasco, 2021), Nicaragua, Costa Rica (Ibrahim, Villanueva and Mora, 2009), Uruguay and several other cases.

New Zealand is a pioneering country in the study of SPS in temperate regions. These systems were incorporated into the forestry practices of timber plantations (mainly exotic Pinus radiata plantations) in 1969 (Hawke, 1991). Subsequently, different trees of several species have been established on farms to combine livestock and timber production (Benavides *et al*., 2009). A similar approach to silvopastoralism can be seen in Australia, with sheep and Pinus radiata. The country, however, features a wide range of silvopastoral approaches, especially in the Queensland region, where their economic performance has been studied.

Regarding East Asia, silvopastoralism in China is typically found in the semiarid northwestern areas, where different tree species have been planted in pastures to improve soil properties, protect soil from wind erosion and provide shade for animals (Zou and Sanford, 1990). However, there is less information on traditional SPS where trees have not recently been specifically planted for fodder. In India, there are several SPS adapted to different conditions, from tropic-humid to arid zones (Yadav *et al*., 2019), but there is less information on silvopastoral activity oriented to small ruminants or traditionally practised forest grazing. Recent studies point to the importance of silvopastoralism for ecosystem restoration (Kumar *et al.,* 2022). However, rules banning pastoralists from grazing in forest areas could seriously affect those systems and the people behind them, even if their work is recognized. Other Asian traditional tree-based farming systems have evolved as a strategy, based on their traditional knowledge, to cope with droughts. Currently, those traditional systems are failing due to climate change, increasing human and livestock populations and higher demand for different products (Soni *et al*., 2016). Modern SPS with simplified designs are a sustainable alternative to increase production.

Central Asia is another area where silvopastoralism has been traditionally practised, along with transhumant and nomadic pastoralism with close links to specific dryland forests and lands with trees. Outstanding examples of silvopastoralism emanate from the Turkish Mountains, such as the raising of Anatolian black goats (Geray, Özden and Sezgin, 2003). SPS such as windbreakers and hedgerows are also found in Mongolia and Central Asia (Stanturf and Mansourian, 2020). Climate conditions and water scarcity are deteriorating in Central Asia, driven by climate change and over-intensification of agriculture, which is threatening traditional livelihoods. Silvopastoralism and other agroforestry systems are also seen as a potential alternative to sustain local livestock production (Djanibekov *et al*., 2015).

Silvopastoralism in Europe has been a subject of multidisciplinary research

over the last decades. Traditional southern European and Mediterranean SPS have attracted much scientific attention. They are both bearers of sustainable and multifunctional food production systems and providers of key ES, including several of the most important biodiversity hotspots in Mediterranean Countries (San Miguel-Ayanz, 2005: Mosquera-Losada and Prabhu, 2019; Moreno and Pulido, 2012). *Dehesas* in Spain and *montados* in Portugal are the best known and most carefully studied at all levels (Pinto-Correia *et al*., 2021), but examples can also be found in Cyprus, France, Greece and Italy. Nevertheless, other European countries in the Northwest, Central Europe (Hungary, Romania) and the East (Ukraine) also feature examples of traditional working and historic SPS (Mosquera-Losada, Rigueiro and McAdam, 2005).

The Mediterranean is a silvopastoralism hotspot with a wide diversity of approaches, systems and governance mechanisms (Pinto-Correia *et al*., 2021). North African silvopastoralism on common lands has been advanced in the area through initiatives reviving traditional governance systems, such as *agdals*, to manage and protect production and services. These initiatives also incorporate a clear strategy to promote the values and services delivered by silvopastoral areas (see Moroccan case study).

Mediterranean governance mechanisms such as *hima* and *agdal* provide key lessons around developing sound silvopastoral management tools, such as transhumance, multifunctionality, multispecies, rotation, specific silvicultural strategies, and so on, (Dominguez *et al*., 2012; Chebli *et al*., 2021; El Aayadi, Araba and Jouven, 2021). Several authors have vindicated their use and enhancement (Naghizadeh *et al*., 2021; Herrera, Davies and Manzano, 2013). Moreover, Near East regions partially share these conditions and boast a wide-ranging heritage of silvopastoralism in their rural areas (Uğurlu, Roleček and Bergmeier, 2012). Following this path, various North African and Near East countries are currently updating their legal instruments to include the protection and regulation of existing grazing in forest lands and silvopastoral systems and provide a framework for its sustainable development (See case study 16 on Lebanon and case study 17 on Morocco under theme 3 on pages 110 and 117).

African drylands boast a great variety of trees, shrubs, grasses, herbs and grazing animals and demonstrate a diversity of silvopastoral practices adapted to almost all environmental and social conditions. African pastoral and silvopastoral peoples have often relied on trees and shrubs to feed their animals, especially in dry seasons. Savannahs provide fuelwood, fodder, fruits and other products. Shrubs and trees often offer better nutritional properties than grasses and constitute the primary feed input for goats and often sheep during droughts and dry seasons. Goats in the Turkana Region obtain their main feed supply (up to 98 percent in dry seasons) by browsing trees and shrubs (Rocheleau, Weber and Field-Juma, 1988). Nomadic and mobile pastoralists often plan their routes upon key forest-based resources, not only for feed but for fruits, herbs and other products. Besides this, they have shown capacity for and interest in managing savannahs and forested areas to improve their livelihoods, taking care and even planting high-value species

such as *Acacia tortilis*, *Tamarindus indica*, or *Balanites aegyptiaca* in north Kenya.

Traditional SPS store local and traditional knowledge on the organization of trees and shrubs to boost their contribution to feed during dry seasons and other services, considering species composition, production, canopies, distribution, density, phenology and other attributes when choosing and working with these species. A participatory study in the southern Guinea savannah, in Nigeria (Jamala, Oke and Fajemisin, 2016) concluded that livestock breeders had useful knowledge of fodder tree species that should be integrated into further projects. This work analysed four different grassland-based livestock systems from subsistence to semi-intensive, concluding that 48 percent of them used fodder from trees and shrubs during the dry season and 91 percent during the rainy season. Moreover, feed from trees and shrubs amounted to over 50 percent of the total intake in 70 percent of the cases during the dry season and 80 percent during the wet season.

Silvopastoral and agrosilvopastoral systems are also widespread in East Africa (Jama and Zeila, 2005). A participatory experiment laboratory-field work performed in Ethiopia showed that there was no correlation between local appreciation of indigenous fodder trees or shrubs for widening their use, nor any ethnicity-based differences regarding the preferences for fodder species (Balehegn, Eik and Tesfay, 2015).

A silvopastoralism approach combined with community management has proved to be a good combination to restore East African rangelands and savannahs (Reij *et al*., 2020) aiming to increase the number of trees and shrubs and the services they provide, not only as fodder but also to harvest fruits, fuelwood, gums and resins. Mobile pastoralism has proven to be an asset in those restoration initiatives.

In southern Africa, grazing livestock is raised mostly in ranches and communal farms, over rangelands under different conditions, but little research has been carried out regarding the silvopastoral use of land (Kgosikoma, Mojeremane and Harvie, 2015).

Preserving Brazil's Cerrado richness through land degradation neutrality mechanisms

The rangelands of the Brazilian *Cerrado* drylands provide valuable ecosystem services, including biodiversity, recreational opportunities, water yield, erosion control, forest products, carbon sequestration, and so on. However, as global demand for soy is growing, the region accounts for 90 percent of the country's production and land prices are quite low, conversion to crops has already destroyed nearly half of the biome's native vegetation. This loss is reducing key capacities of the landscape, such as carbon storage and water regulation, as well as future food production and revenues.

A study compared two options – a business as usual (BAU) scenario, which sees continued land use and conversion, with a "land degradation neutral" (LDN) scenario, which projects a curtailment of expanded soy cultivation avoiding the occupation of pastures, between 2021 and 2050.

The BAU scenario that extrapolates past land cover trends into the future predicted that croplands will increase by 23 million ha, from 26.4 million ha in 2019 to 49.0 million ha. Thus, native *Cerrado* vegetation will decline by 17.6 million ha by 2050. This conversion to crops leads to reduced productivity of soy and jeopardizes the capacity of mitigating climate change and maintaining climate stability. Modelled data show how the loss of 86 million ha. results in a 125 mm decline in precipitation at a drop rate of 0.02 percent per million ha the following year.

However, land degradation can be halted, stopping conversion of native *Cerrado* vegetation. The LDN scenario is evaluated against the BAU scenario using the FAO Ex-Ante Carbon-balance Tool (EX-ACT) to estimate changes in carbon balance. The result is encouraging. While the BAU scenario estimates the emission of 264 million tonnes of carbon dioxide equivalent (CO_2eq) per year, the LDN model identifies savings of 372 CO_2eq per ha. Shifting soy production to alternative systems (and silvopastoralism emerges as one of the most suitable), could in theory, produce potential benefits from carbon credits around USD 25.1–58.5 billion (in present value terms). Conversely, climate-related damage costs and loss of native *Cerrado* land are expected to reach USD 133 billion by 2050 and losses to agricultural productivity will amount to a total of USD 105 billion by the same year. Besides, additional market-based instruments such as ecosystem services payments – official low-interest credit lines for low-carbon agriculture and development of ecotourism – can contribute to internalizing ecosystem service benefits. On the flip side, land ownership costs and taxes can also be used to internalize negative externalities.

The LDN option would bring tangible benefits to farmers in terms of increased income. Under the BAU scenario, over the 2021–2050 period, farmers can expect an average net income of USD 409/ha/year in present value terms. Under the LDN scenario, the figure reaches USD 523/ha/year. There are already silvopastoral initiatives developing in similar regions, as illustrated by the Case study on the Espinaço region that also provides guidance to facilitate the implementation of SPS based in native vegetation.

Haddad, F.F., Blicharska, M., Westerberg, V., Riccardi, T. and Costa, L. 2022. *Valuing, restoring and managing "presumed dryland": Cerrado, Miombo–Mopane woodlands and the Qinghai–Tibetan Plateau*. Forestry Working Paper No. 30. Rome, FAO. https://doi.org/10.4060/cc0110en

Despite their territorial span, many silvopastoral systems in drylands share common features and threats (Plieninger and Huntsinger, 2018). Changing fire regimes, insufficient or excessive tree regeneration, wildlife population dynamics, climate change, changing hydrologic regimes, livestock production economics, depopulation of rural areas, abandonment of traditional practices, agricultural intensification and conversion to ex-urban residences are all part of the picture (Underwood *et al*., 2009), as well as conflicts with other land users. Unfortunately, dependence on management can put a silvopastoral landscape under pressure

when the goals and priorities of markets and economies change (Manning, Fischer and Lindenmayer, 2006). For example, traditional management practices that once created the open woodlands of Europe and North America are lost or on the wane, putting these systems at risk (Hartel, Plieninger and Varga, 2015) as is already the case with European silvopastoral systems meant to feed working animals.

At research and management levels, controversies and pending debates are ongoing, with significant impacts on the consideration of silvopastoralism as a sustainable production and management system for drylands, in addition to the support given to silvopastoral initiatives aiming to improve its role. The first debate concerns opening forests to contribute to their adaptation and to wildfire prevention. While controversial, some authors claim that the thinning of woods is a suitable strategy with clear benefits in terms of climate change (Collalti *et al.*, 2018). On the other hand, certain challenges to this kind of management related to provision of ES need to be considered. Several projects in Europe (e.g. SUDOE "Open to Preserve" or LIFE "Montserrat") aim to identify and implement management measures to preserve open areas and the ES they provide.

Forest restoration projects often try to recover dense forests using the dispersed planting of trees as the main path of restoration. This position has been contested by rangeland scientists (Vetter, 2020), arguing that this perception is rooted in persistent theories on forests and desertification that widely shaped colonial policy and practice and remain influential in today's science-policy frameworks. At the same time, rangelands and open ecosystems (including savannahs and other lands with trees) have been neglected due to insufficient understanding of the ecology of drylands and grassy biomes that encourage afforestation, grazing restriction and fire suppression, with negative impacts on hydrology, carbon storage, biodiversity, livestock production and pastoral livelihoods (ibid.).

A silvopastoral approach, considering the mosaics of different land uses including open and dense forests, grasslands and other land use (all linked by sustainable grazing schemes) can resolve this debate, advocating for a more flexible and functional concept of forests and forests lands in dry areas and applying a more sensitive perspective of the role of rangelands in dryland restoration.

2.4 IS SILVOPASTORALISM ECONOMICALLY PROFITABLE?

Little information is available to assess the economic benefits of silvopastoralism. The use of forest resources as source of fodder and additional revenue is common among pastoralists, but there is scarce data available on their actual value (Wane *et al.*, 2020). However, the research cited in this section represents sound evidence that silvopastoralism can perform better than single-crop or monospecific livestock farming systems under similar conditions.

Economic advantages of silvopastoralism

The Global Review of the Economics of Pastoralism (Hatfield and Davies, 2006) highlights the economic value of dryland complementary products, such as gum, rubber, honey and medicinal plants, especially in international markets. These are

of particular value to rural communities who suffer through seasons of drought, allowing them to sell these products to generate income when traditional crops are failing. In eastern Mauritania, for example, many forestry products still grow in harsh conditions, including fruits (*Ziziphus mauritiana*), pods of *Acacia nilotica* and gum Arabic *(Acacia senegal)* (Shine and Dunford, 2016).

In the United States of America, a comparative analysis was performed between a silvopastoral system and four different monocultures (soybeans, rice, cattle and pine plantations) including land expectation value, equivalent annual income and rate of return. The results showed that the profitability of SPS is comparable to other land-use systems under similar conditions while SPS also boasted a quality and quantity of wildlife habitat absent from other systems. This provides opportunities for additional income, incorporating wildlife-related activities such as hunting leases (Husak and Grado, 2002).

In northern Nigeria, a rapid rural appraisal was used to determine the benefits of silvopastoralism. During the extended dry periods, there was a severe scarcity of feed, which prompted the use of silvopasture (Oladele, 2005). In interviews, farmers said that silvopastures increased the availability of non-timber forest products, provision of shade and shelter for animals in harsh temperatures, improved pasture feeding and the provision of fuel wood (ibid.).

In Queensland, Australia, clearing the forest and woodland for grazing cattle is still common and silvopastoralism is yet to be encouraged (Francis *et al*., 2022). However, modelled case studies suggest that SPS in native forest environments can be financially viable (Francis *et al*., 2022). Research has demonstrated that the economic potential of implementing SPS in private native spotted gum regrowth forests was substantially higher than re-clearing it for cattle production (ibid., Venn, 2022). The development of this research is summarized in the Australian case study number 5 on page 51. While many of these studies highlight the potential for economic return through the use of SPS, only a few studies provide solid data to support the economic case for SPS.

A study from Latin America quantified the positive benefits of silvopastoral systems on both production and productivity (Chará *et al*., 2017). Economic analysis of different intensified SPS in Latin America found that income generated was far higher than investment in all cases, with several of them reporting remarkable profits of USD 1 500 or more per hectare, clearly demonstrating that SPS can be financially solid (Chará *et al*., 2019). SPS in these cases can be simply established by adding trees or tree-forested land to a grassland-based production system, shifting from conventional cattle ranching to a cattle-based intensive silvopastoral system.

A similar result was obtained in Galicia, Spain, where two types of SPS were compared to both forestry and extensive livestock production and were found to obtain a higher productive return from open forest silvopastoral system over forestry or monospecific livestock production (Fernández-Núñez, Rigueiro-Rodríguez and Mosquera-Losada, 2009). The same happened in northern India, where some Jhansi dryland areas increased their production tenfold through a

ten-year silvopastoral plan rotation that improved yield and forage quality (Yadav *et al*., 2019).

Considering the proven economic benefits of SPS and their potential for upscaling, there is a need for further studies to be carried out on the economic performance of dryland silvopastoral approaches. This will provide further evidence of the economic benefits of silvopastoralism and encourage its implementation.

The multifunctional economy of silvopastoralist systems

It is necessary to consider a few important characteristics of silvopastoralism in order to analyse SPS through an economic lens. First, silvopastoralism depends on natural resources provided by forests and rangelands. The level of external inputs is low and the level of autonomy is high, meaning that the system's economic success is highly dependent on the natural conditions of the given area.

Second, silvopastoralism is multifunctional. The same production system delivers different products, often with different production cycles. Usually, this diversified production is sustained by the flexibility and short-term decision-making of pastoralists, which combines the specificities of animal production with the seasonal or long-term cycles of wood production. Importantly, silvopastoralism does not require exclusive access to the land, so additional and complementary uses are often possible in those lands, including recreational, hunting and nature conservation, all of which can contribute to overall system performance. While these interlinking economic activities present a real opportunity to generate income, the various cycles of each production timeline make the economic benefits hard to quantify.

One of the key economic characteristics of SPS is increased biomass fluxes. Photosynthetic rates, nitrogen fixation, nutrient recycling and biomass production are all accelerated (Pérez-Lombardini *et al*., 2021). Biomass consumption by livestock removes a higher portion of the ecosystem's primary production. Thus, more biomass is circulating in the system, increasing production rates. This increased biomass tempers weather conditions and increases the capacity of water storage, also activating microbial soil life and increasing fertility, allowing the system to provide high-quality products (including, for example, mushrooms, berries, cork, and gums) and increasing potential income for local communities.

Economic resilience is another important characteristic of SPS. This relies on diversification, market stability and developed safety nets, including risk management tools, access to financial and insurance and early warning systems. So far, participatory research on SPS in Latin America has shown a high level of economic resilience in both traditional SPS, such as Caívas in Brazil (Hanisch *et al*., 2019) and modern SPS (Pérez-Lombardini *et al*., 2021) analysed in both cases using the sustainability assessment of food and agriculture systems (SAFA) framework (FAO, 2014b).

Lastly, livestock is the backbone of these production systems and its mobility is crucial to the system's success. Rotation, transhumance, or directed grazing are integral instruments of the system, removing biomass where needed and

transferring fertility that can be applied to different lands. Mobility is necessary to allow land to rest and prevent overgrazing.

On the other hand, silvopastoralism is a labour-intensive, specialized production system. Developed countries have a weaker capacity to adopt silvopastoralism, as the income obtained by the production system is insufficient to cover the wages of the specialized works needed to keep the system functioning. However, when key improvements can be adopted, SPS would also increase employment opportunities.

In summary, silvopastoralism combines several production elements and strategies that are balanced and integrated into a production unit, each element contributing to the others: grazing removes biomass and fertilizes the soil, trees provide shade, shelter and fodder and bushes provide additional fodder, as so do agricultural residues. These interrelationships are displayed in the conceptual framework of this paper (see Figure 3 page 8) and have the potential to bring significant economic benefits to rural communities.

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Chapter 3: A framework for applying the silvopastoral approach to restoring dryland forests

As explained in the previous chapter, SPS in drylands vary from single-land-unit-delimited SPS to open-land mosaics. Complexity increases across this span by adding new patches of land, different value chains and new internal and external links. This complexity makes management more difficult but also contributes to developing some key properties of those systems as shown in Table 2, such as flexibility, adaptation capacity and ultimately, resilience (Cinner and Barnes, 2019; Preiser *et al*., 2018). As they grow in complexity, forests and trees also increase their capacity to cope with the harsh and uncertain conditions that prevail in drylands. However, the tensions between silvopastoral production and other agricultural production, unstable markets and value chains, and the pressure from food systems and policies will put a strain on the forests and trees supporting silvopastoral activities, increasing the difficulties of keeping the system up and running. Accordingly, integrated land use planning and management in drylands demand flexible and participatory management schemes. Such management must integrate several goals, multiactor interactions and uncertain environmental conditions in a comprehensive decision-making framework that is able to balance the different benefits, trade-offs, productions and services in a way that ensures both performance and sustainability.

Consequently, the conceptual framework displayed in Figure 3, has been designed for this forestry paper as an attempt to understand how silvopastoralists can simultaneously manage soils and water, pastures, woody plants (including trees) and livestock. The framework also acknowledges their interlinkages and the adaptation of the whole system to different drivers and pressures, both external and internal, addressing the social-ecological interaction and the paths to build adaptive and resilient production systems. Accordingly, the conceptual framework relies on four critical aspects of decision-making: institutions, knowledge and innovation, risk management, and finance and livelihoods.

Three main assertions can be drawn out of this proposed framework. First, management systems, even those with a top-down structure, require the participation of the different decision-making agents to keep all elements active and productive. Second, negotiation between parties addressing the balances and trade-offs in a given management approach is instrumental to success, such

that a management system needs to provide the conditions for this negotiation to happen safely and positively. Third, in interactions between forests, trees and livestock, with different interests and negotiations at stake, conflicts are inevitable, so conflict-solving mechanisms are needed to ensure positive outcomes.

There are many examples of successful silvopastoral systems all around the world, most commonly dryland-based. For instance, "model farm" (or "*finca modelo*" in Spanish) is a predetermined farmland where sustainable grazing is associated with ES and ecological forest restoration and protection. Integrated forest, crop and livestock production systems may increase crop diversity and resilience while providing a consistent source of animal source foods. These systems should be systematically analysed for key learnings. FAO has already developed a number of field projects addressing the relationship between pastoralism and forests and holds an extensive knowledge on the subject, as well as a wide network of partners with deep experience in the issues at hand. For example, there are many projects in Latin America and the Mediterranean, where silvopastoral systems historically include sustainable production and forest management in extensive farms. Building scientific evidence in favour of this approach can also feed discussions at the international level, in particular through the Koronivia Joint Work on Agriculture under the UNFCCC. Proven, low-cost, practical solutions are necessary to trigger climate finance towards the sustainable transformation of agricultural sectors, including silvopastoralism, while ensuring the preservation of natural capital and food security. This technical paper collected 17 case studies (See Table 5) with the aim of paving a way to curb deforestation and help to transform agriculture and food systems in dryland forests, woodlands and rangelands.

As explained in the methodology (section 1.4), the advisory committee grouped the seventeen case studies into three themes (i) multifunctionality of silvopastoral approach for improving production, economics, nutrition and livelihoods of dryland communities; (ii) SPS' contribution to ecosystem health, restoration and provision of its services; and (iii) SPS' contribution to climate change resilience and adaptation and improved governance.

The analysis of the case studies relies on the conceptual framework in order to provide innovative solutions to:

- Keep dryland silvopastoral systems active and productive and contribute to livelihoods, food security and the development of people and communities depending on them.
- Upscale, update and enhance those SPS to improve sustainable production in drylands, extending its benefits under a participatory framework driven by producers and local stakeholders.
- Preserve and enhance the ES that are provided by dryland forests and land with trees, using the silvopastoral approach to fine-tune those services and ensure their long-term delivery.
- Improve the use of silvopastoralism in land management, which already contributes to reducing environmental risks and preserving the natural values

of land.

- Enhance SPS' contribution to the restoration of forest and woody ecosystems in drylands, fighting desertification and contributing to land degradation neutrality and mitigation of climate change.
- Improve the management of soil organic matter to increase their levels, microbial activity and their capacity for carbon storage, contributing to ecosystem restoration.
- Rescue, update and implement a heritage of knowledge strategies and instruments that have allowed the survival of silvopastoralism and its adaptation since prehistoric times at a scale of work that makes a difference in today's global scenario.

The next sections present the 17 case studies under three themes on how silvopastoralism: 1) is a multifunctional approach for improving production, economics, nutrition and livelihoods of dryland communities; 2) contributes to ecosystem health, restoration and provision of its services; and 3) contributes to climate change resilience and adaptation and improves governance.

Chapter 4 analyses the lessons learnt from the case studies, and Chapter 5 targets landscape planners and decision-makers towards formulating different investment and resource mobilization strategies to achieve the desired impact.

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A: Theme 1: Silvopastoralism is a multifunctional approach for improving production, economics, nutrition and livelihoods of dryland communities

Although pastoral livestock farming is subject to a debate about low productivity (output/head), grazing livestock farming systems use natural resources and generate animal production with high efficiency and mainly feeding on fibres that are unsuitable for human consumption. The agroecological interest of the silvopastoral system consists of this function of producing more with less. The efficiency of this system must be analysed in terms of production, economy, nutrition and living conditions for pastoral communities. It is important to note that the role of grazing in the global food system remains central. Half of the biomass consumed by animals in the world comes from grazed resources, that is, grass and tree leaves (Herrero et al., 2013). These resources are obtained through livestock mobility, often underestimated by public policies that generally favour intensified sedentary livestock production systems. The availability of natural resources for grazing supports the economic, social and ecological sustainability of the supply of livestock products. Moreover, pastoral and agropastoral systems develop mainly in dry regions (hot or cold) in response to the spatiotemporal variability of resource availability.

In dry regions, pastures consist of two main resources for food production: herbaceous and woody biomass. These two resources could produce diversified foods, both vegetal and TASF. Pastoral livestock production is characterized by variability in climatic conditions influencing the availability of woody biomass. However, trees are a strategic resource for herders, enabling them to cope with often-difficult climatic conditions (drought, cold, etc.). Trees in dryland grazing represent an important element for ecological sustainability and mitigation of environmental impacts of livestock production. Pastoral, silvopastoral and agrosilvopastoral systems remain difficult to account for, as the different farming systems may be interrelated. Steinfeld *et al.,* (2005) found that pasture-based systems accounted for about 30 percent of the world's livestock; about 30 percent of red meat production; and 20 percent of milk production. In mixed systems with

rainfed agriculture, livestock contributes to two-thirds of red meat production and almost 95 percent of milk production. In developing countries, this production based on pasture or mixed systems is slightly higher.

Silvopastoralism promotes the diversified production income of forests, trees and livestock, mainly in less productive seasons, and contributes to an improvement in the quality and variety of local diets by adding TASF. An FAO study in Argentina, Chad and Mongolia (Wane *et al*., 2020) showed the multifunctional contribution of livestock grazing in woods and grasslands to socioeconomic dimensions, especially in remote areas. Animals, milk, hides, and so on, represent between 38 and 74 percent of monetary income and self-consumption represents between 8 and 37 percent of additional income. At the country level, agrosilvopastoral systems contribute 10 percent of the national GDP in Chad and Mongolia and about 1 percent in Argentina. If self-consumption is included, this contribution rises to almost 20 percent in Chad and Mongolia and 1.5 percent in Argentina.

Public policies that highlight silvopastoralism sometimes misunderstand the sustainable development issues of these systems and support guidelines for the investment or management of silvopastoral land that do not consider the multifunctionality of these ecosystems beyond their economic contribution. The debate between land sparing and land sharing is an example. Conservation policies aimed at only environmental objectives can severely damage the livelihoods of Indigenous Peoples who are dependent on natural resources. In a bid to preserve resources, pastoral communities may find themselves evicted or deprived of their livelihoods and their actual and potential role in natural resource management neglected. This situation can also lead to a radicalization of conflicts between pastoralists and states. On the other hand, livestock policies may not consider the vulnerability of social-ecological systems by building infrastructure that contributes direct or indirectly to ecological degradation. Some policies could better integrate the role of trees in the management of pastoral lands and promote inclusive forms of action for the sustainable management of tree pastures. The challenge of approaching silvopastoral systems is therefore essential in the socioeconomic promotion of sustainable livestock production.

There are promising examples of silvopastoral schemes that were adapted to different regional conditions and show available solutions for each challenge. This chapter spotlights cases from the silvopastoral systems in Brazil, South Sudan, Kenya, Chile and Australia and their potential contribution to improving production, economics and community livelihoods with special consideration of different criteria and potential outcomes from combining trees and forests with grazing livestock as shown in Table 3.

CASE STUDY 1: THE FUNDO DE PASTO AGROSILVOPASTORAL SYSTEM

The communities of "*fundos de pasto*" have lived for centuries in their territories by exploiting and conserving the Caatinga, a semi-arid tropical vegetation in northeastern Brazil, and balancing conservation of natural resources and the ecosystem with social advancement and preserving their way of life. The Caatinga

biome is one of the most diverse dryland ecosystems and consists of tropical and subtropical dry, broadleaf forests, covering most of the Brazilian Northeast. It covers an area of about 844 453 km^2, equivalent to 10 percent of the Brazilian territory (Leal, *et al.,* 2005). The conservationist management of the *fundos de pasto* is based on agroecological principles. It deals with applying agroforestry system techniques that integrate agricultural, fruit gathering, forestry and livestock production, generating diverse and productive landscapes. Traditional management favours the conservation of the Caatinga and its biodiversity, contributing to the conservation and reproduction of endemic species and the maintenance of soil coverage and functionality, as a unique system worldwide, fundamental to guaranteeing the permanence and survival of rural communities in the Brazilian semiarid (Araujo Filho, 2013; Bianchini, 2018; Carvalho *et al.*, 2020).

Fundos de pasto: historical background

The *fundo e fecho de pasto*, better known as *fundos de pasto*, are traditional institutions for common land management in the Brazilian semiarid region, mainly dedicated to extensive livestock farming, crops and agroextractivism in the Caatinga. The origin of the *fundos de pasto* communities dates back to the seventeenth century, with the decline in both economic and political power of the large landowners who colonized the northeastern drylands. The communities of rural workers constituted a mix of Indigenous Peoples, mestizos and blacks, who occupied the borderlands of the big estates, fought for land rights, aiming to remain on those marginal lands, far from the farms' headquarters and considered the "bottom of the pastures", giving rise to the nomenclature of the communities of *fundo de pasto* (Ferraro Junior, 2008; Alcântara and Germani, 2009). These communities started their main activity – extensive goat production in the Caatinga – using fenceless common forestlands. Processing the integration of the peasant economy into the market economy began in the Northeast in the 1950s, intensifying agrarian conflicts in the region. The *fundos de pasto* then collectively organized themselves to defend their ownership and land rights. They also advocated for the right to communally raise their livestock, according to the traditional production systems and ways of life that had already been developing in the region for over a century (Santos, 2010; Alcântara and Germani, 2009). According to the survey conducted by the Geografar research group (2020), currently a total of 625 communities of *fundo e fecho de pasto* are registered, distributed across 56 municipalities in northern, western and southwestern Bahia.

Characteristics of the pastureland agricultural system

A *fundos de pasto* community is both a production system and a social reproduction system that is typical of the semiarid region of Bahia. Those communities are characterized by extensive livestock production, mainly small ruminants, complemented by gathering and processing of native fruit, timber resources, herbal medicines and honey. All these activities are usually carried out

in common lands. The common rangelands used for grazing livestock constitute a central pillar of sociability in the communities of *fundos de pasto*, thus they cannot be appropriated for private or individual use. Social relations and solidarity among individuals were historically built based on family and friendship links (Alcântara, 2004). Water resources, such as *iagarapés* (streams) and *barreiros* (ponds), are also common goods that are collectively managed by the community, even if they are located on individual or family-managed lands.

The extensive raising of goats, sheep, poultry, pigs, horses and bees constitute the main livestock production activities. These species are key for the families' livelihoods, as they need little water and food supply to thrive, while they are better adapted to the soil and climatic conditions of the Caatinga. Besides this, there is also a culture of cattle raising, even though cattle is not the most recommended species for this region, due to the high cost of management (Araújo Filho, 2013). Subsistence agriculture is also present in those communities, generally practised in lands for both individual (family) and collective use (Carvalho, 2020; Alcântara and Germani, 2009). Land tenure and access rights of both common and family lands are governed by formal and informal customary rules transmitted over generations. Communities also practice gathering activities that include fruit harvesting from the native species of Caatinga as umbu, licuri, passion fruit and araticum. Wood is also extracted for the construction of buildings, farmyards and fences and finally, families and communities also rely on picking herbs and medicinal plants. (Carvalho, 2020; Santos, 2010).

Crops are mainly in individual (family) orchards, based on rainfed systems and intercropping of yields such as beans, corn, cassava, potatoes, pumpkins, fruit trees, as well as a wide range of vegetables. Those crops are mainly intended for subsistence and food security for the families, whereas the productive surplus is destined for sale, exchange, storage or donations within the community. Collective fields are intended mainly for growing fodder and commercial crops, such as sisal, palm and mandacaru (Bianchini, 2018; Santos, 2010). The agricultural activity is typically rotational, when the first signs of degradation are detected the crop area is left to fallow and the activity rotated to another area, promoting the restoration of soil fertility and the regeneration of the agroecosystem (Primavesi, 2016).

Fundo de pasto in restoring woody dryland by managing their livestock grazing

The resources in *fundos de pasto* communities are characteristically managed as a common good. To increase and improve the provision of goods and services from sustainable management and restoration of dryland forest and agroforestry in the Caatinga Biome in Brazil, in 2016, FAO initiated a project entitled "Reversing Desertification Process in Susceptible Areas of Brazil: Sustainable Agroforestry Practices and Biodiversity Conservation" funded by the Global Environment Facility. The project worked closely with *fundo de pasto* and trained the different land users on how to monitor the limits on the use of their common goods while guaranteeing the long-term productivity of the land and improving

resilience and livelihoods. The *fundos de pasto* communities have developed a strategy that preserves the agrobiodiversity by maintaining forest areas through multidimensional production systems and tactics, despite having certain ecological and technical limits in the management of the Caatinga (Ferraro Junior, 2008; Bianchini, 2018). Free-range livestock graze on the Caatinga, getting their feed from its great diversity of native plants. Grazing intensity is controlled by stocking rotation of animals through different woodlands. In addition, forage is also used as supplementary feed before releasing the animals, which is intended to guarantee an adequate source for the animals during the dry season, reducing the impact of animal grazing in times of senescence, when ecosystem fragility is greater. Those dry-season forages, both native and exotic, are on the community fields. This coping strategy adapts the production system to the environmental dynamics of the semiarid region. Recently, communities have developed the practice of *re Caatingamento* (Caatinga recovery), which consists of the environmental restoration of degraded areas.

Other agroecological aspects observed in traditional systems include the use of crop rotation and intercropping in agricultural practices, recycling materials between the different production systems, promoting the rational use of local genetic diversity and germplasm seed stocks, adopting low-input social technologies and exploring the sustainability potential of the diversified range of Caatinga microenvironments.

Fundos de pasto as a productive model to improve the common management of complex and multifunctional agroecosystems

Analysis of this case based on the conceptual framework (*Figure* 3) and the proposed criteria (Table 3) shows that the *fundos de pasto* systems contribute to the conservation of natural resources in semiarid lands. They also enhance subsistence and food security of their rural communities by combining the production of diverse foods from integrated production practices (livestock, agriculture and extraction of wild fruits) with sound outputs in term of resilience and ecosystem health.

According to data from Bem Diverso (2020), in six communities analysed, formed by 357 families, it is estimated that the herd of goats is 4 200 heads, 4 695 sheep, 730 cattle and 300 pigs, in addition to the productive potential of umbu fruits of 6 071.55 tons/year and, 122 tons/year of Licuri. Another work carried out estimated the total gross value of the production of the *fundos de pasto* in a family production unit which considered the market values for products derived from livestock, agricultural and extractive production.

In total, the annual gross value of production is equivalent to BRL 17 860.00 (USD 3 299 USD) Of this total, the equivalent of BRL 4 000 (USD 739) was allocated for food and self-consumption by the families, BRL 5 360 (USD 990) was marketed and the remaining BRL 8 500 (USD 1 570 USD) was not marketed or consumed, being destined for stock formation (Fonseca, Salviano and Freitas, 2019).

This diversity of production and food crops is reflected in the consumption of varied and nutritionally rich foods. Therefore, this system can produce enough quality food for all families, guaranteeing their food and nutritional security independently of external inputs. It also contributes to keeping people in the countryside. *Fundos de pasto* production is also an important source of income for the communities, mainly through the marketing of animal products and native fruit, either fresh or processed. The cooperative COOPERCUC is a case of success in the region. It is a cooperative of *fundos de pasto* communities with a production capacity of 200 tons/year of processed products of native fruits, including sweets, juices, pulps, jellies, and jams.

Ecosystem services generated and conservation of the Caatinga

The grasslands are well-conserved areas of Caatinga and are extremely important due to the fragility of this unique biome in the world, which is facing increasingly intense degradation and desertification processes. Compared to other products and occupation models, the grasslands are more effective in conserving the Caatinga. According to ICMBio (2022), only 48 percent of the Caatinga does not suffer any type of degradation. However, studies such as that of Bianchini (2019) point out that in areas occupied by *fundos de pasto* communities, the area of preserved native vegetation can exceed 85 percent. Additionally, recent studies analysed the diversity of plant species present in the *fundos de pasto* systems, finding high biodiversity and a high degree of endemism, reaching 57 percent, which reinforces the importance of the *fundos de pasto* management system for Caatinga conservation. (Bem Diverso, 2020).

Threats and challenges underpinning the *fundo de pasto* efforts

Despite the rational management of natural resources, some negative impacts are observed on the local agroecosystems of these communities, mainly affecting land use and governance. Land degradation is a clear threat, caused mainly by overgrazing and deforestation, often caused by external people. The strategy carried out by *fundos de pasto* communities to fight overgrazing and degradation of the Caatinga consists of *re Caatingamento*, characterized by the replanting and assisted recovery of the Caatinga biome in strategic locations, contributing to turning the tide of the Caatinga desertification process through the sustainable use of common goods (IRPAA, 2019).

Moreover, the main threats to the territories of the *fundos de pasto* communities are mining projects, wind farms, construction of energy dams and water reservoirs for irrigated production and the expansion of large export-oriented farms. The communities are strongly organized to face these threats at different levels, from local associations to the state level. The State Articulation of Communities of *fundo e fecho dbe pasto* represents and politically articulates all the communities of *fundos de pasto* in the state of Bahia which contribute to the needed proper governance to promote the conservation and restoration of the degraded dry forest in Caatinga.

For more information

https://geografar.ufba.br/sites/geografar.ufba.br/files/relatoriofinal_mapeamentoffp_vf.pdf;
www.youtube.com/watch?v=lmee-Armg_8

CASE STUDY 2: A DRYLAND CATTLE CORRIDOR AS A RESILIENCE OPTION FOR COMMUNITIES AND A RESTORATION OPTION IN SOUTH SUDAN

Terekeka county drylands are a dry area in an administrative division of Centra Equatoria in South Sudan, well known as the Cattle Corridor, stretching between Northern-Eastern Talli, Tindillo to Southwestern Mundari-Bura and extending to Rijong and Rego southwards of Terekeka county, encompassing about 80 000 ha. It is characterized by irregular rainfall, up to 1 350 mm per year, in its cattle corridor. A fragile natural environment, rich in biodiversity, supports the livelihoods of the Mundari communities. Pastoralism is the most widespread land-use system in these lands, which host about 50 percent of the county's livestock, mainly kept by agropastoral and pastoral peoples. Despite the large numbers of cattle, the Terekeka county drylands constitute a severe poverty hotspot.

Mundari dryland cattle corridor

The Mundari dry land cattle corridor is a mosaic of denuded landscapes, with forest woodland and savannah grassland with scattered trees. This area is mainly used for grazing livestock and other agrosilvopastoral practices. The typology of rangelands in the area includes grasslands, woodlands and bush clusters encompassing about 87.8 percent of the total rangelands. There are some additional resources provided by valuable tree plants like gum acacias. The land holds remarkable natural value, as well as abiotic interaction. Unfortunately, this area is suffering significant changes in land use as indicated by the decreasing woodland cover, driven by fuelwood recollection for charcoal production, clearing and conversion to grazing (accompanied by extraction of valuable dry land tree species such as *Vittelaria pardoxa*, *Tamarindus indicus*, *Acacia senegal* and *Balamitea*, currently threatened with local extinction).

The Mundari communities in the three sites of the cattle corridor practise a mixed land-use system combining silvopastoralism with agroparklands established around the watershed area of the TaPari basin and the Nile water catchment area. However, traditionally practised pastoralism and agrosilvopastoralism account for about one-third of the Mundari population. Up to 95 percent of pastoralists and agropastoralists use the semiarid rangelands, raising their indigenous breeds. Those SPS apply a concept of natural regeneration that has contributed to preserving its vast heritage. Traditional livestock production practices contribute to livelihoods with manure production, traction and work power, being instrumental for both livelihood safety nets and the ecological conservation of the area. The main instruments Mundari uses for land management are enclosures and individual homestead tree planting for rehabilitating grazing lands.

The communities have been experiencing the effects of severe land degradation

caused by multiple factors, including increasing human and animal population and the reduction of the available natural resources. In addition, climate variability, intensification of natural resource use and socioeconomic drivers, such as urbanization, mining activities, population growth and immigration, all of which have contributed to increase vulnerability.

Community support programme in Talli, Tindillo and Mundari Bura

Between 2016 and 2020, FAO funded and implemented a pastoralist livelihoods project initiated by Norwegian People Aid (NPA) to support rural development, water management and forestry, along with non-governmental organizations (NGOs) and women groups in South Sudan. The community support programme in Talli, Tindillo and Mundari Bura contributed to strengthening resilient pastoral livelihoods in facing the impact of climate change and conflict. NPA has introduced the agroforestry approach in the area, targeting small-scale farmers and focused on increased food security, energy security and wealth creation. The project focused on the process of mainstreaming sustainable land management (SLM) by local communities in the cattle corridor. First, it considered biodiversity conservation through integrated land-use management as a key to planning climate change adaptation and mitigation action. Second, it piloted the silvopastoralism technology to improve the communities‘ livelihoods and land management. The primary aim of the project was to improve local land governance in the project area. Accordingly, it promoted the diversification of income-generation activities, such as small-scale irrigation schemes, handicrafts, and so on, and built the institutional capacities for integrated land use management and planning, helping to reduce the stress on the Corridor’s natural resources. Moreover, the project facilitated the introduction and development of alternative gender-sensitive energy sources, watershed management technologies and agroforestry practices, such as water harvesting, mulching and minimum tillage, in addition to awareness-raising on water and sanitation care issues.

The key pillar of the project was to revive the Indigenous pastoral practices of soil and water conservation activities through protecting and resting periods and the development of afforestation actions to arrest soil erosion, taking into consideration women’s empowerment and the specific conflict-solving actions in the Corridor. This silvopastoral perspective is also applied to fight the widespread loss of tree biodiversity using a land management framework to promote revegetation, land rehabilitation, soil conservation and tree planting. It also makes use of agroparkland practices, including understory grazing, promoting enclosures, night kraal (already considered by producers, who in some cases have started those practices on their own), and silvopastoral mechanisms to enhance livelihoods and the safety net during dry seasons and droughts.

Alternative livelihoods are needed in restoring the woody drylands and managing the livestock grazing

Although NPA has been working with 200–350 farmers for up to five years, civil wars have affected South Sudan and prevented the project from achieving

more impact on the ground. Producers suffered heavy losses of livestock, food stocks of sorghum, milk and meat and access to markets. However, the evaluation conducted showed the communities' enthusiasm for their Indigenous silvopastoralism practices along with the project's capacity-building activities. Higher livestock production has also been reported as well as improved Indigenous silvopastoralism technology and food security. Up to 25 community-based farmer groups, both female and male, were trained and supported in using better agricultural tools and improved strategies to face the loss of their natural resources due to the conflict. Local marketing techniques and capacity were also crucial in improving the communities' resilience during the conflict. Besides, the community also improved local production through an auction market and mobilizing microfinance activities.

Finally, tackling challenges to ensure sustainable livelihoods in the cattle corridor includes dealing with several livestock-related management issues, for instance land clearing and overexploitation of natural resources. Farmer-to- farmer learning through exchange visits has enabled farmers to learn by doing, resulting in peer demonstrations of better agroforestry management practices, including tree plantation periods. This has been promoted in the three cattle corridor sites by supporting training actions targeting selected local communities and farmer groups. Lessons learned from this project resulted in a call for upscaling the use of watershed management activities (such as gully rehabilitation or water harvesting), alternative energy sources and forest regeneration.

Analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) show that the Mundari dryland cattle corridor provides clear examples of development strategies that are appropriate for any country context. Key among the lessons learned is the emphasis on inclusive approaches that involves all programme beneficiaries, particularly women, in designing and executing SLM actions that simultaneously address livelihood improvement, ecosystem conservation, and land rehabilitation and therefore increase resilience.

The conflict scenario is also threatening silvopastoralism and the ecosystems that support it. Positive action is needed to address some of the most pressing challenges. A first challenge implies the application of a holistic and comprehensive perspective, understanding the interconnectedness of the different elements of the system and contributing to a SLM model, supported by different technologies such as conservation, rotational grazing or night kraal, also generating capacity and social cohesion. The implementation of this integrated development approach may encourage agroforestry systems and scale some good practices, improving soil fertility and hydrological management.

Moreover, a balance needs to be found between short-term benefits and future impacts. Any intervention project must include food security and poverty reduction through a diversified livelihoods strategy and enhance resilience of livestock and trees production systems. Community-specific action should be geared towards sustainable livelihoods and pragmatic actions.

Considering social issues is also instrumental in improving this scenario. There

is a need to address local people's attitudes, behaviour and perception as a means to improving their action. The attitudes of local groups shift towards building capacity and adopting innovative technology transfer to address land degradation issues. Besides, technical backstopping for community-level activities can result in the increased adoption of best practices, thus improving their well -being and livelihoods.

For more information

NPA Assessment report: Awerial, Yirol, Mundri and Terekeka Counties (2014).
IRNA Report: Reggo and Tali payam in Terekeka County, Centra Equotoria State 2015.

CASE STUDY 3: LIVESTOCK GRAZING MANAGEMENT REGIMES IN DRYLAND FORESTS AND SILVOPASTORAL SYSTEMS IN KENYA

The Kenyan drylands are characterized by marginal and extreme weather conditions with low rainfall, low crop productivity and sometimes extreme failure, high poverty levels and extreme pressure on natural resources to sustain people's livelihoods. Kenya's arid and semiarid lands (ASAL) support more than 30 percent of the Kenyan population and over 50 percent of the country's livestock populations (the entire camel population, 50 percent of the cattle and some 70 percent of all sheep and goats), which accounts for 90 percent of employment and more than 95 percent of family incomes (Government of Kenya, 2003). Many households in those ASAL live in extreme poverty (Homewood, Trench and Brockington, 2012; Jane, Mwangi and Nkurumwa, 2013).

Characteristics of pastoralism in the Kenyan drylands

Pastoralism is the main economic activity and provides food and income to 80 percent of the population in this region. Twenty percent of those pastoralists practice agropastoralism (Trench and Makee, 1994). Complementary wages and cash for buying maize, the staple food, are derived mainly from livestock sales.

Pastoralism is directly influenced by two factors. First, livestock diversity, optimized by the use of varied browsing and grazing fodder types; and second, quality, achieved through livestock mobility and rights to land, livestock, grazing and browsing resources, water, trees, honey and other harvested products. It is governed by a developed system of norms, values, beliefs and practices for achieving sustainable resource use and adjustment in livestock numbers based on existing land resources. In most cases, nomadic pastoralists usually prefer to seek access to natural resources to sustain their livestock rather than reduce their herd size. The main livestock includes goats, sheep, cattle and camels.

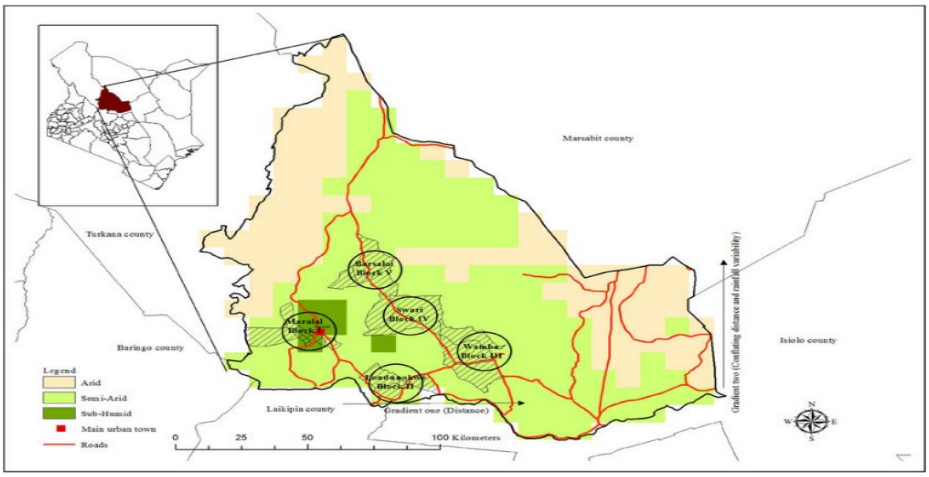
The Samburu's silvopastoral system

Samburu County lies within the northern parts of the Great Rift Valley in Kenya (Figure 6). The plateau hosting the Leroghi Forest rises to 2 580 m above sea level receiving an annual rainfall of between 900 and 1 500 mm. The county lies

within a dryland environment and covers an area of 21 022 square kilometres with a population density of 11 inhabitants per km² (Samburu County Government, 2018). Eighty percent of the population depends entirely on pastoralism for livelihood. The county is ranked the second poorest in Kenya (Government of Kenya, 2009), with poverty levels at 63 percent.

Closed canopy forest (Sirat), characteristic of dry zones and *Juniperus-Podocarpus* evergreen forest, accounts for 25 percent of the total forest cover and is an important source of dry season water (sere), pasture, fodder, food, honey and medicine. Samburu pastoralists regulate pastoral resources under a communal land tenure system among the local community, allowing access to different areas depending on rainfall and vegetation within Samburu territory. Herd mobility takes place on a regular but gradual basis; during the rainy season or in areas where pastures are abundant, the elders set certain areas aside for either settlement or grazing. Mobility may include short-distance daily circular movements of livestock around the homestead, here referred to as mobility, to large-scale movements and combinations of these.

FIGURE 6:
Location study area.



Source: ***Karanja, S., Bulte, E., Giller, K., Ndiwa, N., Kifugo, S., Mcintire, J., Herrero, M. & Rufino, M.*** 2016. Livestock wealth and social capital as insurance against climate risk: A case study of Samburu County in Kenya. Agricultural Systems. 146. 44-54. 10.1016/j.agsy. 2016.04. 004.

The grazing schemes were established in 1936 in Leroghi and in the entirety of Samburu in the 1950s, where various forms of grazing and stock control were practised. However, grazing remained a highly contested and controversial issue between the colonial administrators and Samburu pastoralists. People could move freely over the landscape again and there were no restrictions on the number of livestock owned by individuals (Trench, 1997). Between 1961 and 1965, elders in Samburu lowlands decided to start managing settlement and grazing regimes through the customary communal regulation known as *nkwe ngishu* ('head of a cow'), keeping grass for cattle, (Pas, 2018).

In 1972, under the Land Act of 1968, the Group Representative Officer started to demarcate land on the Lerodgi plateau for both individual and group ranches to formalize land tenure. Group ranches are similar to previous grazing schemes as they are demarcated pasture areas aimed at controlling grazing, encouraging settlement and commercializing livestock (Pas, 2018).

An analysis carried out in Sanataa forest block, located in the northwest corner of Leroghi forest (Figure 9) on household characteristics, livestock production, forest use, constraints and opportunities among other issues showed that the silvopastoral land-use system is practised predominantly by the Samburu traditional pastoralists. The forest provides an important source of dry-season pasture (97 percent) and fodder (62 percent), mainly during the dry months of January to March every year. For the rest of the period (April to December), grazing is confined to the plains and high grounds. The local communities usually take refuge in the forest as a mechanism for climate risk prevention.

Forest-grazed management plan contributes to ecosystem restoration.

The silvopastoralists' adaptation and survival strategies entail multiple species and diverse herd typologies, herd mobility and splitting. Their silvopastoral activity largely relies on adaptability and flexibility over managed ecosystems rather than environmental stability. Conflict around natural resources is central to the sustainable management of pasture and water, making it necessary to understand the past and present conflicts and mismanagement and the lack of sound technology. Factors influencing conflict include the pastoralists' attitudes and perceptions around grazing livestock, the economic benefits associated with forest grazing, the existing early drought warning and mitigation measures, cattle rustling practices associated with payment of bride wealth, and social status associated with large herd sizes. Lastly, the rapid increase in human and livestock populations and the consequences of environmental degradation have resulted in the breakdown of traditional authority structures for regulating access, control and management of grazing and water resources and poor livestock market access due to limited infrastructure and cultural barriers. The natural resource/man ratio has largely remained dynamic due to the rapid increase in the human population, thus necessitating a change in strategy towards natural resource use efficiency.

The analysis presented in this case study led to a series of advanced recommendations that can contribute to devising an improved silvopastoral attitude for Samburu County. These recommendations rely on building and strengthening the capacity of local pastoral communities and institutions to sustainably regulate the access, control, use and disposal of forests and grazing lands while diversifying income-generating activities. Besides this, there is a clear need to invest in the rehabilitation and restoration of degraded lands and watering points through promoting natural regeneration, planting and managing fodder trees, fodder banks and leguminous species, while increasing controlled browsing for enhanced beef and milk production. It is also important to encourage local community interest in nature-based enterprises such as seedling production,

herbal medicine and beekeeping. Local and traditional knowledge is key for these developments and should be mobilized and enriched with research, scientific advancement and technology. Additionally, management could be enriched by adopting better management practices, including livestock diversity and mobility, adoption of livestock breeds adapted to local conditions, and herd splitting.

A forest-based grazing management plan or guidelines could be a necessary step forward, especially if locally managed, flexible and responsive enough to drive technological and socioeconomic changes in a pastoral environment. In addition, sustainable forest planning tools should reduce risks by promoting sustainable management actions, including: 1) destocking; 2) sustainable dry-season grazing; 3) pasture harvesting and storage systems; 4) minimizing incidences of fire risks; 5) arranging forestland use; 6) fining or removing squatters and abusers; and 7) observing the current presidential ban on harvesting/logging in the forest.

Positive and negative impacts associated with silvopastoral land use system

Analysis of this case study based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that silvopastoral land use holds varied benefits and suffers from threats – and therefore demands positive collective action at different levels.

The negative impacts associated with unsustainable grazing in the forest include overgrazing, browsing and lopping of the rangeland resources that result in deterioration in the quality and quantity of grass, herbage and fodder resources (ibid.). Pasture management using fire negatively affects natural regeneration, destroying seedlings and saplings of insufficient bark thickness, especially within the community forest reserve. The other consequences of grazing, especially within the Lerodgi forest, include: loss of biodiversity due to overgrazing; increased soil erosion; increased fire risks due to honey hunting and associated activities; the spread of tick-borne diseases; water catchment destruction; loss of endangered animals and plant species that are endemic to certain areas; loss of biodiversity due to frequent drought; rapid conversion of pastureland to cropland; and a shrinking resource base due to ecological degradation, episodic droughts and insecurity resulting in overgrazed and overstocked pastures, and usually leading to soil erosion and environmental degradation. Droughts, which can cause heavy losses of up to 80 percent of livestock, diseases, high stocking rates, insufficient watering points, trampling and pasture degradation and other indiscriminate and illegal human activities are also contributors to land degradation. Similarly, access to livestock markets and limited technical knowledge is poor or limited.

Challenges and opportunities for effective forest-grazed management plans

The difficult situation of the livestock sector in Samburu County can be attributed to the low productivity of the traditional livestock breeds, poor milk handling techniques and lack of animal feeds, especially during drought. It is also affected by cattle rustling, animal diseases, incidences of insecurity, competition for water and pasture, poor livestock markets, breakdown of community cultural and traditional structures and depletion of rangeland pasture and trees (Luvanda, 2014).

However, the local communities in Samburu County have consistently devised mechanisms for coping with adverse weather conditions. Some of the measures being proposed for enhanced resilience include: the use of livestock breeds that can improve production out of local resources; formulation of community by-laws aimed at enhancing environmental conservation; shifting of settlement for the degraded environment to recover; a temporary ban on dryland forest grazing; use of fines to discipline by-law breakers; diversifying the consumption of meat and milk with other foodstuffs; adoption of new approaches to farming; and diversifying sources of income from livestock production such as milk production. The silvopastoral land-use system needs to be well integrated into other land-use systems for enhanced environmental conservation.

Improving an integrated land-use-governance system is crucial to sustaining ecosystem goods and services. The National Policy for the Sustainable Development of Northern Kenya and other dryland areas is recognized for its specific stipulations regarding mobile livelihoods – hence the need to develop governance and services that target mobile populations. Kenya Vision 2030 promotes the inclusion of pastoralists in national development to end perceived marginalization and make drylands equal to the rest of Kenya. The Kenyan Constitution (2010) and the Community Land Act (2016) which perceive pastoralists' livelihoods as valuable, must be operationalized. This will allow the documented rights to their land to initiate a shift in thinking about pastoral land use. Simultaneously, it will promote the use of customary institutions for managing resources and (cross-border) mobility (Pas, 2018).

For more information

11-0204-Luvanda (sciencebeingjournal.com)

CASE STUDY 4: THE SUMMERING–WINTERING PRACTICE IN MANAGING THE SOUTHERN ANDES DRYLAND FOREST AND MOUNTAINS IN CHILE

In the mountain territories of the southern Chilean Andes, the practice of *veranada–invernada* (*walugtuwe - pukemtuwe* in Mapuzungún, or summering–wintering in English) can be considered a type of transhumance that allows patterns of land use based on local ecological knowledge to be observed. This system demonstrates the strong relationship between the Mapuche Pewenche communities and the nature they inhabit. Transhumance in the Cordillera of

the Southern Andes is mainly based on the coordinated use of areas that reach complementary maximums of plant production over time, making it possible to avoid critical periods in each zone and taking advantage of the resources when they are at their highest production and quality stage. Thus, both the Andean grasslands are managed as fodder for the feeding of small livestock and forests of Araucaria (*Araucaria araucana*), to extract its seed, called *pewen* or *piñón* (pine nut). Araucaria is considered a "living fossil" (Gedda, 2010) and is classified as an endangered species.

Grazing livestock, forests and trees in the Mapuche Pewenche lands

However, the practice of summering–wintering cannot be considered just a mechanism for the exploitation of natural resources – it is also a substantial part of a more complex ancestral cultural system. This practice holds an enormous territorial, economic, cultural and environmental significance for the Mapuche Pewenche communities. Applying a territorial perspective, Martínez (2015) states that this is a form of articulation that makes it possible to define spaces, develop social practices and also integrate different modes of production. Thus, these practices of "ancestralization" help to strengthen the territoriality and identity of such communities.

Economically, the summering practices represent production areas for small producers, who carry out their small livestock production practices and harvest non-timber forest products, such as the aforementioned pine nut. Communities also collect other forest fruits and medicinal herbs or *lawen*. After harvesting, pine nuts are mainly sold unprocessed, in bulk, or packed in sacks, to small or medium-sized traders who act as intermediaries and resell them in fairs and supermarkets (Cortés *et al*., 2019). The availability of pine nuts varies from year to year (Donoso, 2006) and is strongly threatened by the effects of water scarcity and climate change (CONAF, 2016), with significant impacts on those communities. Pine nut trade is an important activity although it is an unstable source of income for the collecting families, varying depending on the annual productivity. Prices oscillate between less than USD 1 per kg of bulk pine nuts in years of abundance years up to USD 3.5 in a bad year. (Cortés *et al*., 2019).

Besides harvesting, some families have ventured into the production of processed foods or preparations, such as pine nut flour, biscuits, coffee, *muday* (a fermented drink), or *catutos* (fried dough). Those foods are consumed at home or as part of the gastronomic displays that take place in traditional festivals, such as the *Fiesta del Piñón* in Pewenco Bajo, an event that takes place every year in April with horse-riding (*jineteadas*), country dances and other cultural manifestations.

To apply a cultural perspective, the *veranada* is an activity that contributes to identity building and reaffirmation, knowledge-sharing and the intergenerational transmission of experience and practices among family and community members. The *veranadas* are symbolic areas for the development of spirituality, as they constitute places where the spirits (*Ngen*) of nature (*Ngen Mawida* Mountains; *Ngen Ko*, water*; Ngen Lof*, the community; and *Ngen Pewen*, araucarias)

dwell. From an environmental perspective, the coordinated use of the territory, considering its natural cycles, is evidence of deeply-rooted local ecological knowledge (*conocimiento ecológico local*, CEL), which allows for sustainable and communal management of the available resources. This knowledge is defined as "a cumulative body of knowledge, practices and beliefs that have evolved through adaptive processes and are transferred through generations by cultural transmission, playing a fundamental role as a strategic guideline for sustainable natural resource management" (Berkes, Colding and Folke, 2000; Cortés *et al*.,2019). It can be exemplified by how the practice of harvesting is developed, identifying different types of pine nuts according to the time of year: *Puyén*, which is harvested from late December to early February; *Yaten*, from late February to early May and *Guillín*, which is harvested from the beginning of the snow melt, between September and November. Each of them has a particular use and way of harvesting, ranging from the direct collection on the ground, climbing the tree and even socially questioned practices such as cutting off the heads of green pine nuts, which is repudiated by the people, as it damages the tree.

A singular practice in the Chilean Andean Araucanía: the veranada of Lof Pedro Currilem

The Lof Pedro Currilem is a community comprised of 56 families, approximately 300 people. It is located in Pewenco Bajo, in the commune of Lonquimay, 180 kilometres from the regional capital Temuco and 25 kilometres from the Pino Hachado international pass (Marchant, 2019). The toponymy of this place comes from Mapuzungun: *Pewenco* means "araucaria water" (*pewen* "araucaria" and *-co* "water")". In terms of the use its inhabitants make of the territory, this mountain area (*mawida*) can be subdivided into two: Pewenco Alto and Pewenco Bajo. In winter, the community settles in Pewenco Bajo where they have their fixed residences, as well as culturally significant landmarks such as the Epu-Pewen School, the Pewenche Kimun Cultural Centre, the cemetery (*eltuwe*), the field where the *nguillatun* is celebrated and the community's *rehue* (altar). Pewenco Bajo is also the place of access to wider mobility through the international route G-181, which connects with other populated centres.

The beginning of the summer season does not have a fixed date. It is usually up to the *Lonko* of the community to set a date, after a mandatory check on the animals' status, performed by the agriculture and livestock services. In addition, they consider the climatic aspects that will influence the location of the summer posts or *rukos*. The *rukos* are a type of handmade shelter built to shelter the summer visitors during the transhumant journey, made of wood and branches from the collection of dead firewood in the vicinity. Those shelters have corrals added for better control of the livestock. The summering period lasts 4–6 months. Conversely, the beginning of the wintering season in Pewenco is marked by the first frosts of the year, and is therefore an indicator for the beginning of the transhumance to the lower parts of the valley, which takes place between the end of March and May.

Transhumant routes take place on the communities' lands, originally coming from the process of handing over individual property titles in 1985. This process took place in the context of the transfer of public lands to Mapuche communities, through the land titling law promoted by Augusto Pinochet's dictatorship (*Comisión Verdad Histórica y Nuevo Trato,* 2008). Despite this individualized ownership, which on average amounts to half a hectare, land use for this purpose is communal, although this category of use is not yet recognized by the Chilean state. Besides, this Lof is adjacent to the Alto Bio National Reserve, managed by the National Forestry Corporation (CONAF). Reserve areas managed by state institutions are forbidden to keep livestock, which has led to conflicts with the administration of these spaces. The *Lonko* of the community publicly stated in 2015 the "need for the Mapuche to be able to participate in CONAF" (Romero, 2020).

The summer season begins with the *arreo* herding the animals' uphill from the wintering area (specifically from sheds located around the houses and the cultural centre in Pewenco Bajo) to the summer pastures. This transhumance is carried out in different stages and moments of the year, depending on the type of livestock being moved and the distance between the wintering area and the summer pastures. The transhumance is performed using tracks or gravel roads, by groups of men, normally on horseback and without any help from mechanical means (such as vehicles), a practice observed in other *veranadas* in the region. Each family takes around 15–20 large animals (cattle, horses) and a larger number of smaller animals (sheep, goats) up the mountain.

Piñoneo (pine nut harvesting) is the most important practice in the summer season. It is mainly carried out by children and women in the *pinalerías* or Araucaria forests (*pewento*). It starts in private family lands (*bajos o pülom*) and, once finished, harvesting starts on the customary common lands. Harvesting constitutes an important summer activity encompassing the aforementioned economic and sociocultural relevance with its role as the main food source for both people and livestock. The collection of timber products (dry or dead Araucaria and Ñirre -*Notophagus antarctica* – firewood, in low volumes) is also carried out in a complementary manner. This firewood is mainly used for the construction of the *rukos* and for heating homes. They also collect *picoyo*, a dry hook of dead araucaria that contains a high quantity of crystallized resin and is used to make handicrafts. Herbs are also collected and used by women, *machis* and those members of the community who know the medical use of herbs (*lawentuchefe*). The forms of use of these herbs vary between common preparations such as infusions, poultices, rubs or washes; they are generally kept dry and used for both human and veterinary medicine. The development of all these types of collective work fosters intergenerational cooperation and contributes to community cohesion.

Finally, knowledge transfer or *kimun* is one of the most relevant symbolic activities of the transhumant practice. The summer camp brings together different members and generations of the community; in these facilities, local history (*epew*) is transmitted orally from elders to young people and children. Stories are shared

to show how the world, life and the significance of the different places within the Mapuche Pewenche worldview are interpreted. In this sense, summer is an opportunity to experience nature and understand the specificity of each of its components.

Transhumance opportunities and challenges in restoring the trees cover for better livelihoods

Trees and their seeds, such as *Araucaria araucana* forests and the *pewen*, are closely linked to the livelihoods of communities, generating a sense of place and allowing the establishment of socioecological links between humans and non-humans (Ibarra *et al*., 2022). In the *veranada–invernada* exercise, humans, plants, seeds and animals form a complex and dynamic socioecological system that shapes a unique landscape where the biocultural memory emerges and achieves long-term sustainability. However, in the political and cultural context, various processes and state-driven policies resulting from the fragmentation of land ownership, extractive uses of mountain territory and blocked access rights to forests in protected areas for harvesting practices, are generating stressful situations that threaten the continuity of these key activities for both communities and the landscape.

Moreover, an emerging controversy between the Chilean State and the Indigenous Communities over land management and biodiversity conservation in the Pewen forests is a pending issue, which should be resolved by granting the communities that depend on these resources, a greater say in decision-making affecting their livelihoods. The International Labour Organization Convention 169 states that Indigenous Peoples have specific characteristics that differentiate them from other national societies, such as worldview, cultural values, ancestral territory, institutions and authorities. Accordingly, the governance of natural resources must be based on these local institutions and customary laws, acknowledging their legitimate rights over their ancestral territories, even if declared as protected areas. It is worth noting that Pewenche communities have adopted different mechanisms for the care of the forests, for example temporarily preventing livestock access to the gathering places, banning unsustainable harvesting practices, such as tree-shearing or beating or cutting of pine nut green hooks (Cortés, *et al*., 2019). This reflects the sacredness that the species holds and its valuation not only economically but also culturally and spiritually due to the protection it provides.

Analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) and the proposed criteria (Table 4) show that the practice of summering and wintering exemplifies the deep connection and knowledge of these Indigenous Peoples of both mountain rangelands and forest. The series of practices and activities associated with the management of livestock and the use of forests reveal a profound link between the communities and their environment, combining transhumance with the collection of non-timber forest products from the temperate rainforest such as the Pewen of Araucaria Araucana,

as well as firewood collection. These practices are embodied in a robust range of local ecological knowledge. They help generate cultural representation and exemplify how the work of human communities is embodied in their territory. They therefore transform this geographical space into a unique, living space, complete with specific meanings and values that cannot be extrapolated to other cases, which contributes to strengthening local and community identity.

The case study is dedicated to the memory of Nivaldo Romero Cañiumir, Lonko of Lof Pewenco, who worked tirelessly for the promotion and protection of the culture, rights and recognition of the Mapuche Pewenche people.

For more information:

Marchant (2019). La práctica trashumante pehuenche en la Araucanía andina: una forma de construir y habitar los territorios de montaña del sur de Chile. http://dx.Doi.org/10.4067/S0718-34022019000300187

CASE STUDY 5: FINANCIAL PERFORMANCE OF SILVOPASTORAL SYSTEMS IN QUEENSLAND, AUSTRALIA

Queensland is the second-largest state in Australia, covering 172.7 million hectares and 83 percent of its area is suitable for grazing. Queensland's red meat industry plays a key role in Australia's economy, accounting for 48.1 percent of Australian beef and veal production in 2017-2018 (Meat and Livestock Australia, 2018). Not surprisingly, methane emissions from enteric fermentation are a key contributor to Queensland's GHG emissions. In 2018, Australia's total GHG emissions were 537.4 million tons (Mt) of carbon dioxide equivalent (CO_2-e) and beef cattle methane emissions were responsible for 75 percent (15.5 Mt CO_2-e) of Queensland's agricultural GHG emissions (Department of Industry, Science, Energy and Resources, National Inventory Report 2018). The Australian red meat and livestock industry, through Meat and Livestock Australia (2018), has stated an aspiration to become carbon neutral by 2030 (CN30). Avoiding deforestation by managing vegetation for the mutual benefit of production (meat and timber) and afforestation for capturing carbon while producing timber are mechanisms that are expected to help meet the CN30 target (Mayberry *et al*., 2019).

Queensland has 51.8 million hectares of native forest and approximately 233 000 ha of softwood plantations. Integration of trees and livestock is not a new concept; in Queensland, livestock grazing beneath forest or woodland was adopted soon after European settlement in the nineteenth century and remains a current activity over a vast area. In this case, we aimed to summarize previous research carried out on the financial performance of silvopastoral systems in Queensland, and undertake a landscape-scale analysis of the financial performance of managing native spotted gum regrowth forest as SPS, relative to re-clearing for grazing.

Opportunities for silvopastoral systems in private native forest

There are large areas of privately owned commercially productive native forest in Queensland that may be suitable for SPS. Lewis *et al.,* (2020) characterized the commercially productive private native forest within a 24.4m ha study area in southern Queensland and northern New South Wales and identified ~2.6 m ha of commercially important forest that was potentially harvestable under current vegetation legislation. Most of this private native forest is grazed by cattle and the understory pastures are considered a key forage resource. A range of native pasture species grows beneath the native forest canopy, depending on the region and land types. However, forage productivity under unmanaged native forests is inherently low, in terms of both quantity and quality. Adoption of a silvopastoral approach can improve forest stand productivity by reducing competition between trees and providing an opportunity to enhance pasture productivity through decreased competition (for light, soil water and nutrients) between trees and pasture (Schulke 2012; Peri *et al.,* 2016).

In Queensland, forest types are classified by species composition and age-class structure, such as remnant and regrowth forests. Remnant forest refers to forest that has reached 70 percent and 50 percent of undisturbed canopy height and cover, respectively. Forest management is subject to the Vegetation Management Act 1999, which regulates the clearing of vegetation in Queensland. Thinning and clearing are allowed in Category X areas of this Act, where vegetation is not regulated by vegetation management laws (thinning is also allowed in some other categories under approval from the regulatory agency). The main advantage of establishing silvopastoralism in regrowth forests is that minimal upfront costs are needed to ensure the establishment of trees compared to plantation establishment. Exclusion of fire and grazing for 1–2 years can be enough to promote the regrowth of trees from a seed bank or lignotubers with high-value regrowth species such as spotted gum, forest red gum (*E. tereticornis*) and various ironbark, such as narrow-leaved red ironbark *(E. crebra*) and grey ironbark (*E. siderophloia*). Regrowth forests generally grow at a faster rate than remnant forests, due to the lack of suppression from larger trees (Lewis *et al.,* 2020) and have good productive potential when appropriately managed. However, regrowth forests can become very dense in the absence of forest thinning.

Financial performance of SPS in Queensland

In the last two decades, there have been several evaluations of the financial performance of SPS in Queensland, a summary of which is presented in Table 6. These studies spanned a range of different environments, including eucalypt woodlands (Star and Donaghy, 2010) with no timber values included, through to more productive coastal eucalypt forests (Francis *et al.,* 2022) and hardwood plantation forests (Maraseni, Cockfield and Maroulis, 2009). Performance is reported as the net present value (NPV) of gross margins (annual revenues and fewer management costs). Consistent with the international literature (Dangerfield and Harwell, 1990; Bruck *et al.,* 2019; Chizmar *et al.,* 2020), the Queensland

studies suggest SPS can maximize returns to grazers. Only in cases where cattle grazing occurs beneath native forest or woodland without consideration of timber or carbon values was the NPV sometimes negative (Star and Donaghy, 2010; Donaghy *et al.*, 2010; Table 6). In the one plantation example, initially the land was more profitable when cleared for grazing. However, when the carbon price reached USD 1.725 or AUD 2.50 AUD/t CO_2 e (the numbers reported throughout this case study are in AUD except when indicated otherwise), SPS became the most profitable alternative (Maraseni and Cockfield, 2011).

TABLE 6
Financial performance of cattle grazing on cleared land and as part of a silvopastoral system in Queensland

Queensland case studies	Net present Value of gross margins (AUD/ha)*				Source and real discount rate adopted
	Cattle grazing on cleared land	Cattle grazing within native forest	Native forest SPS	Planted forest SPS	
Goldfields	16 to 70	-37 to 1			Star and Donaghy (2010); 5 percent
Silver-leaved ironbark high productivity	81 to 190	-21 to 33			Star and Donaghy (2010); 5 percent
Silver-leaved ironbark low productivity	12 to 101	-39 to -14			Star and Donaghy (2010); 5 percent
Brigalow	320 to 550				Department of Primary Industries and Fisheries (2007), Stephens et al., (2008); 5 percent
Poplar box	130				Department of Primary Industries and Fisheries (2007); 5 percent
Brigalow		-14.7 1	84.1 1	209 1	Donaghy et al., (2010); 6 percent
Poplar box		-1.7 1	137 1	N/A	Donaghy et al., (2010); 6 percent
Kingaroy	3079			2879	Maraseni, Cockfield and Maroulis ., (2009), Maraseni and Cockfield (2011); 6 percent
Gayndah spotted gum-ironbark	661		1 024		Schulke (2012, 2017), Venn (2020); 5 percent
Glenbar spotted gum	49		1 532		Francis et al., (2022); 5percent
Gayndah spotted gum	640		1 406		Francis et al., (2022); 5 percent
Doughboy spotted gum	687		2 396		Francis et al., (2022); 5 percent
Rathdowney spotted gum	92		1 405		Francis et al., (2022); 5 percent

**Notes: 1. These NPV estimates for SPS from Donaghy et al., (2010) are interpreted as the net change relative to grazing returns on cleared land.*

Financial performance of SPS in private native forests at the landscape scale

The four case study properties examined by Francis *et al.,* (2022) are broadly representative of the diversity of regrowth (Category X) spotted gum forest structures and growing conditions in southern Queensland, with mean annual rainfall at the properties varying from 580 mm to 1 140 mm. Industry research partners provided estimates of silvicultural treatment costs, land clearing costs and log stumpage prices in 2018 dollars. Real (adjusted for inflation to 2018) weighted prices meant that live-weight cattle prices in Queensland for the period 2015 to 2018 were used to estimate livestock revenues. A growth-response model for native-forest silvicultural treatment (Lewis *et al.,* 2020) and the Queensland Government Grass Production model, developed by Littleboy and McKeon in 1997, were employed to estimate forest and pasture growth on each case study property over a 20-year investment period. The NPV of gross returns (present value of income from the sale of logs and livestock, less the present value of costs of management) was estimated per hectare for each scenario on the case study properties with a 5 percent real discount rate. Due to the scarcity of financial performance data for SPS in Queensland's native forests, the case study data from Francis *et al.,* (2022) have been adapted to facilitate the estimation of distributions of potential returns to SPS and the clearing of forests for grazing in the landscape scale via a five-step procedure.

First, for analysis, SPS was defined as only the (i) silviculturally treated; and (ii) silviculturally treated and harvested scenarios reported by Francis *et al.,* (2022). The NPVs for these scenarios for each case study property were collated by Francis *et al.,* (2022) and a normal probability density function was applied to these data. Second, to accommodate cattle sale yard price volatility over the past 20 years, the financial performance of clearing regrowth spotted gum forest for grazing was assessed with three alternative real weighted mean live-weight cattle prices in 2018 Australian dollars:

AUD 2.29 /kg, which was the mean real price from 2000 to 2021;

AUD 2.54 /kg, which was the mean real price from 2015 to 2018 (this is also the scenario reported in Francis *et al.,* 2022); and AUD 3.66/kg, which was the mean real price in 2021.

The livestock production levels simulated by Francis *et al.,* (2022) over 20 years were held constant, but the NPVs of gross returns per hectare were estimated for each of the three price levels with a 5 percent real discount rate. Separate probability density functions were fitted to the NPVs estimated at each price level. At the AUD 2.54/kg price, a normal probability density function fitted to the distribution of NPVs resulted in a 14 percent chance of clearing for grazing generating a negative return. The case study property NPVs and probability density function parameters are reported in Table 7.

TABLE78
NPV of gross returns per hectare for the SPS and clear for grazing scenarios for each case study property and probability density function parameters

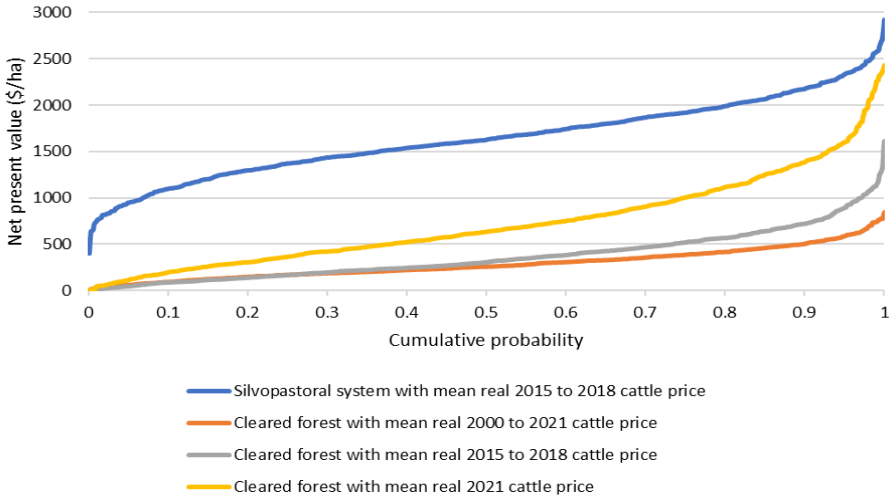
Case study property	NPV (AUD/ha in 2018) and probability density function parameters by scenario			
	Silvopastoral system [a]	Clear for grazing with mean real 2000 to 2021 cattle price	Clear for grazing with mean real 2015 to 2018 cattle price [b]	Clear for grazing with mean real 2021 cattle price
Glenbar	1 484 and 1 532	5	49	291
Gayndah	1 342 and 1 406	528	640	1 143
Doughboy	2 129 and 2 395	570	687	1 210
Rathdowney	1 405 and 1 405	33	92	353
Mean	1637	284	367	749
Standard deviation	396	306	343	495
Weibull a c	N.A	1.8	1.4	1.6
Weibull b c	N.A	320	405	820

Notes: a. this scenario is a combination of the: (i) Silviculturally treated (the first estimate – logs harvested only in year 20); and (ii) Silviculturally treated and harvested (the second estimate – logs harvested in year zero and year 20) scenarios reported in Francis et al., (2022). There is no difference in returns at the Rathdowney property because there were no harvestable logs in year zero.
b. This scenario is the cleared for grazing scenario reported in Francis et al., (2022).
c. These are the fitted Weibull probability density function parameters.

Third, a Monte Carlo simulation was applied to produce 1 000 estimates of NPV per hectare for SPS and for clearing for grazing systems at each cattle price level. This was achieved by generating 1 000 random numbers between 0 and 1 to represent a cumulative probability in the relevant cumulative probability density function and then selecting the NPV estimate associated with that cumulative probability.

Fourth, the NPVs estimated for SPS and clearing for grazing in step three were added and multiplied by 217.7 to provide an estimate of NPV at the landscape scale for the 217 700 ha of spotted gum regrowth forests in southern Queensland. Fifth, steps three and four were repeated 250 times to facilitate the estimation of a 95 percent confidence interval for the NPV of SPS and clearing for grazing at the landscape scale. Figure 7 indicates that returns to SPS in southern Queensland spotted gum regrowth forest are generally expected to financially outperform clearing for grazing. Only with the 2021 mean real cattle price was clearing for grazing found to potentially exceed the median NPV of SPS, with 4.5 percent of simulated grazing operations generating an NPV greater than the median SPS value.

FIGURE 7
Estimated distribution of NPV of gross returns per hectare of the silvopastoral system and clear for grazing scenarios generated by Monte Carlo simulation



Finally, Table 8 reports the mean and 95 percent confidence interval of NPV for the SPS and clear for grazing scenarios at the landscape scale (217 700 ha). SPS resulted in NPVs of AUD 352.6 to 361.6 million (USD 243.3 to 249.5 million), substantially higher than clearing for grazing options (AUD 60.1 to 165.8 million or USD 41.5 - 114.4 million), even at high cattle prices.

TABLE 8:
Net present value of 217 700 ha of southern Queensland regrowth spotted gum forest managed as silvopastoral systems or cleared for grazing

Scenario	Real cattle price	95 percent confidence interval of the NPV for 217,700 ha ($ millions)		
		Lower bound	Mean	Upper bound
Silvopastoral	Mean 2015 to 2018	352.6	356.7	361.6
Clear for grazing	Mean 2001 to 2021	60.1	62.0	63.9
Clear for grazing	Mean 2015 to 2018	77.3	80.2	83.3
Clear for grazing	Mean 2021	154.4	160.0	165.8

The simulated distribution of NPV per hectare and NPV at the landscape scale assumes the four case study properties are representative of the distribution of returns that can be expected from SPS and clearing for grazing in regrowth spotted gum forest in southern Queensland.

The adoption challenges of the silvopastoral system in Queensland

The adoption of SPS remains low in Queensland, where re-clearing of forest and woodland for grazing cattle continues to be a common management practice. Summarizing this case upon the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that the potential for SPS in private native spotted gum regrowth forest, which was estimated to have an average net present value of AUD 356.7 million (USD 246.1 million) at the landscape scale (217 700 ha), is substantially higher than reclearing to maximize cattle production (average NPV of AUD 62–160 million [USD 42.8–110.4 million], depending on cattle prices). However, these studies need to be supported by empirical research in private native forests and plantation forests. Long-term studies that address livestock, timber and pasture productivity are urgently needed in Australia for scientific and demonstration purposes to help encourage landholder adoption.

In addition to the lack of knowledge actually supported by long-term research and extension, there are several governments and market failures that need to be overcome to facilitate greater uptake of SPS in Queensland. For example, landholders exhibit a severe lack of trust in the Queensland Government (Brown *et al.,* 2021) and there have been 40 amendments to vegetation management laws since 2000 (AgForce, 2021). The uncertainty about rights has discouraged native-forest management and caused periods of expedited planned and unplanned clearing to generate less risky income streams from cattle alone, rather than SPS (Simmons *et al.,* 2018). Other impediments to SPS include long payback periods for timber, coupled with the opportunity cost of foregone higher annual cash flow from producing livestock on cleared land. Encouraging investment in SPS will require policies that reduce sovereign risk and provide additional revenue streams for landholders based on the broader public benefits of SPS (e.g. carbon sequestration).

For more information:

Land types: https://futurebeef.com.au/resources/land-types-in-grazing-land-management/.

Queensland ecosystems: www.qld.gov.au/environment/plants-animals/plants/ecosystems

Cattle sale yard price volatility over the past 20 years: http://statistics.mla.com.au/Report/List

Rates of land clearing in Queensland from the 2018-19 SLATS report: www.qld.gov.au/environment/land/management/mapping/statewide-monitoring/slats/slats-reports/2018-19-report

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B: Theme 2: Silvopastoralism contributes to ecosystem health, restoration and provision of its services

The combination of different land uses on silvopastoral lands, the stratified layers of vegetation (trees, shrubs and grasses) and the effect of grazing livestock, under various management and grazing parameters (e.g. stocking, seasonal use, resting, species and breeds used), create a great variety of microclimatic niches and spatial heterogeneity that boosts biodiversity (Rigueiro-Rodríguez *et al.*, 2010). Many of these SPS constitute key global biodiversity hotspots, such as the Brazilian *Cerrado* or the African Miombo woodlands. Silvopastoralism can provide efficient feed conversion, high biodiversity and natural capital, enhanced connectivity between habitat patches and good animal welfare (Broom, Galindo and Murgueitio, 2013). Additionally, silvopastoralism provides a wide range of ES, including provisioning, regulating, supporting and cultural services vital for human well-being (Garrido *et al.*, 2017). Grazing animals are net contributors to soil fertility and nutrient recycling, shrub encroachment control, fire prevention and control, seed dispersal, habitat provision, and preservation of knowledge systems and educational values (Sales-Baptista and Ferraz-de-Oliveira, 2021).

Silvopastoralism has a long history of success in grasslands, savannahs and savannah-like areas, open forests, lands with trees and mosaic landscapes. However, while modern-designed SPS are more suitable for specific projects on the local or regional scale, it is important to actively support traditional pastoralism and silvopastoral approaches, along with any other activities contributing to multifunctional land management. There is a wide range of synergies that could be developed between mobile pastoralism and silvopastoralism, contributing to collaborative land management strategies that can maintain woody rangelands as open, rich and biodiverse areas. There are also controversies around overgrazing and the negative effects of livestock in woodlands that need to be taken into account.

Silvopastoralism contributes to ecosystem health in multiple ways.

Silvopastoralism can be instrumental in halting and reversing forest and land degradation. The combination of carefully managed silviculture and grazing regimes can increase vegetation cover, reduce erosion, increase soil retention and improve the water cycle. The high carbon storage and large area suitable for

silvopastoralism make SPS a strong potential agent to help mitigate global climate change (Hawken, 2017). SPS enhance carbon sequestration both above and below ground, more than other systems (Kay *et al.*, 2019), but this capacity largely relies on the integration of grazing and forest management to optimize carbon storage by grass root systems while increasing tree growth. Additionally, silvopastoralism can contribute to preserving areas with a high risk of wildfires by reducing their fuel load through grazing and browsing, maintaining the accessibility of risk areas and maintaining critical firefighting infrastructures such as forest roads, water sources, or firebreaks. Sound silvopastoral management of lands leads to improvement in herbaceous fodder resources and therefore in pastoral potential (Bourgoin *et al.,* 2019). Specific silvopastoral management tools, such as planning resting periods, are key to keeping the pastures out of degradation (Weber and Horst, 2011). Enclosures and fencing in modern SPS are also important tools to manage the herbaceous carpet and help to implement the grazing and resting cycles.

In the short and medium term, silvopastoralism could be a powerful tool for land restoration. Research shows how SPS with fast-growing leguminous nitrogen-fixing trees can contribute to restoring degraded lands. Stocks of organic matter, carbon and nitrogen, enable leguminous trees to increase the efficiency of nutrient cycling while grazing accelerates this process. Besides, silvopastoralism can contribute to livestock production while compensating for GHG emissions with higher levels of carbon storage. Thus, the recovery of degraded land and sequestering of carbon dioxide at higher rates are key silvopastoral benefits (Solorio *et al.*, 2017).

However, preparing forests and lands with trees for grazing can also increase risks such as deforestation (Öllerer *et al.*, 2019). Importantly, the lack of regulation and changes in land use (often driven by specific market demands or to introduce mechanization), can lead to degradation (FAO, 2014a) especially in traditional silvopastoral systems. Hence, it is vital to identify and manage trade-offs, while taking advantage of potential opportunities for improving silvopastoral approaches.

There are promising examples that fit with conservation goals in designing, restoring and updating silvopastoral activities and using grazing livestock as a land management tool. This section spotlights cases from the silvopastoral systems in Tunisia, Senegal, Spain; Uzbekistan, Burkina Faso and Jordan and their potential contribution to enhancing the health ecosystem restoration and management with special consideration of different criteria and potential outcomes from combining trees and forests with grazing livestock as shown in Table 4.

CASE STUDY 6: SUSTAINABLE SILVOPASTORAL RESTORATION TO PROMOTE ECOSYSTEM SERVICES IN TUNISIA

Rangelands in Tunisia cover approximately 5 566 180 ha, including 2 500 000 ha of collective land, 1 285 000 ha of private land and the remaining rangelands under state care, including 970 000 ha of forest rangelands, 743 300 ha of alfa steppes (*Stipa tenacissima) and* 67 880 ha of state-owned land. These ecosystems play

several functions and provide various services to people but face severe climatic and anthropogenic pressures. Mismanagement of those ecosystems, conversion to farmland, exploitation through selective harvesting, fuel wood removal, charcoal production and livestock overgrazing are significant drivers of large land degradation, habitat change and biodiversity loss, which negatively impact their functions and services (Escadafal, Bacha and Delaître, 1997).

Tunisia is suffering from this situation, with a high proportion of the country's land mass at risk of desertification due to the degradation of natural resources, which has resulted in a substantial decrease in plant diversity, productivity and pastoral value. Mismanagement of natural resources has also contributed to land degradation, exposing ecosystems to climate change and leading to high levels of food insecurity, conflict and reduced livelihood options for pastoralists and smallholder farmers (Harvey *et al*., 2014).

Grazing livestock, forests and trees in Sbaihia site, Zaghouan, Tunisia

Sbaihia Site is an area belonging to the Jimla sector of the governorate of Zaghouan. It suffers from a variable and fluctuating rainfall regime, with an average lower than 400 mm/year. The Jimla sector is an agricultural area, with its land divided between crops (52 percent) and forests and rangelands (48 percent). Agricultural land is mainly dedicated to growing crops that play an important role in supporting the livelihoods of the rural population, such as olive trees, forage crops, legume crops, cereals, vegetables and fruit trees, located in a semiarid region with cold and temperate winters and hot and dry summers.

Sbaihia Site is a state rangeland managed under the authority of the Forestry Department. The site covers an area of around 4 700 hectares and hosts an important ecosystem across the Near East and North Africa region (a mosaic with croplands and rangelands with patches of Aleppo pine and Thuja forests) where the agrosilvopastoral production system is essential for the livelihood of the farming communities. The region is susceptible to climate change. The frequency of extreme weather events is growing and affects the productivity, profitability and sustainability of agricultural production systems, with adverse implications for dietary diversity and nutrition. Over 70 family households inhabit the area, with an average of five persons each. The primary income is generated through extensive small ruminant and olive production.

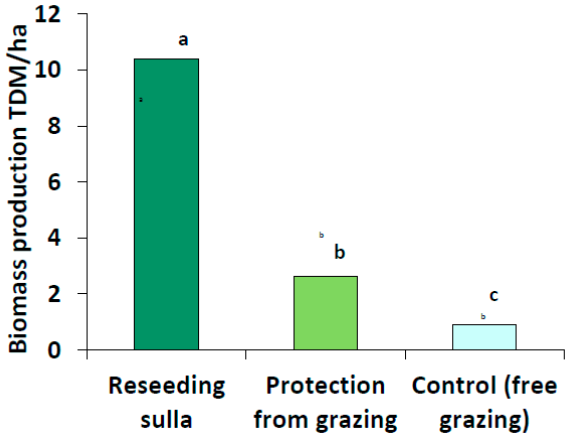
According to the Regional Commissariat for Agricultural Development in Zaghouan, feed resources cover only 60 percent of the needs of the livestock herds, increasing the possibility of overgrazing the rangelands. Pastoral resources consist of fodder production from forest rangelands, natural grasslands and residues of cereal crops. The importance of the areas of land used by agriculture and the topographic configuration of these agricultural lands, combining forests and rangelands with small private land patches, show high potential for use in pastoral practices. Developing the agroforestry potential of the area also includes continuing to grow olive trees (*Olea europaea*) and carob trees (*Ceratonia siliqua*) and aromatic plants. Currently, there is a large group of women who work in the

collection of rosemary (*Rosmarinus officinalis*), lentisk (*Pistacia lentiscus*) and pennyroyal (*Mentha s.p.*) for the distillation of floral water and essential oil. The community-based organization (CBO) has a modern distiller it uses to process raw materials harvested by women and produce floral waters and essential oils. The CBO is also making efforts to market these products by participating in various fairs in the country.

Grazing role in managing and restoring woodland in Sbaihia

A joint project implemented in 2017–2019 by ICARDA, FAO, and the *Direction General des Forêts de Tunisie* – "Sustainable Silvopastoral Restoration to Promote Ecosystem Services" – aimed to improve the productivity and resilience of silvopastoral system. This project assessed the impact of sustainable silvopastoral practices of reseeding ecosystems with sulla (*Hedysarum coronarium*), a native biannual forage legume species providing feed as grazing biomass for livestock, along with services such as soil and water conservation. Regeneration of shrubs was also assessed, including different species of salt bush (*Atriplex* spp.), tree medic (*Medicago arborea)* and spineless cactus pear (*Opuntia ficus-indica*). Each year a similar amount of these plants (500 seedlings of carob tree and 500 seedlings of medic tree, 600 seedlings of salt bush and 3 200 pads of cactus pear) were transplanted to the site. Transplantation is currently ongoing: in 2021 alone over 1 000 carob trees and 250 seedlings of *Rosa canina* were planted. Survival rates for these species have been estimated at 85 percent at least 18- months after their transplantation. For all recorded parameters (dry matter, mineral content, organic matter, forage value, total nitrogenous matter etc.) the highest values were recorded in the sulla reseeded plots, for example in the case of dry matter yield. Under favourable conditions with good rain and deep soils, the biomass recorded at the improved site (sulla reseeding) was 10 times higher than the control, a conventional free-range practice (Figure 8). These results confirm that implementing a proper silvopastoral system improves the pastoral value of the natural ecosystems through increasing the provision of services (e.g. increased forage supply, enhanced livestock productivity, increased soil vegetation cover reducing erosion, increased species richness, etc.). For the restored pilot site, in 2019, the cost of livestock feeding dropped significantly to TND 0.35 per day per head (USD 0.12 USD) in 2019 while at the control site, the cost of feeding was estimated at TND 0.9 (USD 0.3) per day per head.

FIGURE 8
Impact of the two rehabilitation techniques: sulla reseeding and grazing protection on pasture productivity at Sbaihia site in semiarid silvopastoral lands.



Source: Elaborated by case study authors

Soil and water conservation structures were constructed to reduce soil erosion by water and increase water retention. These structures included bench terraces and stone gabions to reduce surface runoff and capture sediments. Four stone gabions were constructed, while manual bench terraces were implemented in an area of 40 ha. Based on calculations done after heavy rainfall events in October 2018, the four stone gabions and the manual benches thus far have preserved at least 4 800 Tm Ha^{-1} $Year^{-1}$ of soil from erosion, while storing at least 280 m^3 of water to be used to water the shrub species planted on these ditches, as well as reducing runoff water loss by approximately 800 m^3/ha. Over time, the strategy of expanding and diversifying well-adapted forage species will be fully integrated with the feeding systems of livestock, yielding more benefits from the silvopastoral approach. Planting forage legume species, such as sulla, is also expected to enhance soil fertility. Besides, Sulla is a melliferous species which allowed local communities to raise honeybee keeping and diversify their income. The 40 ha reseeded by Sulla could host up to 600 hives to be managed within the rehabilitated area.

The establishment of an effective and well-managed CBO is necessary for the overall success of a silvopastoral site. The CBO ensures the implementation of a management plan and sustainable use for the whole site. To this end, an agreement between the silvopastoral community and the local authority has been developed, implementing controlled grazing based on the available forage supply and the livestock demand under an accurate estimation of carrying capacity. A small fee was paid by farmers based on the number of animals to be allowed to graze. Such an arrangement strengthened trust among all stakeholders and increased community sense of ownership. This is important, as restoration is relatively easy to accomplish, but most projects fail at managing the sites for the restoration to progress.

A total of 15 capacity development events and meetings with the local community were held. As a result, 492 participants consisting of local farmers, extension staff, local authorities and students were equipped with skills and information concerning sustainable management of silvopastoral systems. From this total, at least 40 percent of the participants were women, achieving one of the targets of this project – to promote inclusiveness by empowering the participation of women in farming activities within the Sbaihia area and beyond. As part of the capacity-building activities, a new initiative aimed at increasing awareness about the conservation of natural resource base and best practices among pupils in 40 primary schools. This activity was important to introduce natural resource conservation with a focus on vegetation recovery to elementary school pupils at a young age to build their interest and involvement.

Reseeding woody species as a means to recover and conserve the SPS

Checking this case against the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that the Sbaihia initiative contributed to an increase in the silvopastoral production of forage and livestock through halting land degradation and erosion using silvopastoral tools, with clear outcomes in conserving the natural resource base (flora, fauna, soil and water), while improving the livelihoods and resilience of agrosilvopastoral communities, in the target area.

The improvement of silvopastoralism in the site, including water harvesting interventions to alleviate soil erosion, selection and transplant of high nutritive value and palatability shrub and tree species (Carob tree and Tree Medic) and reseeding with sulla, a native herbaceous species, and improved grazing management based on estimated carrying capacity, helped in developing the linkages between seasonal fodder production and livestock husbandry and designing and implementing a silvopasture demonstration.

Management practices resulted in several social and environmental benefits for the local community.

The silvopastoral improvement accomplished in the region of Sbaihia relies on a sound participatory approach with full cooperation from the local population who contributed to the main decisions implemented onsite, such as the species to choose, the management of a site once planted and when to improve the performance of ecosystem service provision within the silvopastoral site. Also, the lessons learned from best practices for soil and water conservation, such as constructing gabions and water harvesting structures highlighted the need to combine those conservation practices with shrub and tree growing and silvopastoral management to maximize the potential of water harvested. The participation of both men and women in this initiative is considered as the main pillar to harness innovative capacities and create long-term mitigation effects of climate change while increasing production.

The successful collaboration, at the national and regional level, among the Directorate-General of Forests of the Ministry of Agriculture, the Regional

Commissariat of Agricultural Development of Zaghouan (represented by the forest service and the water and soils conservation service), the Higher School of Agriculture of Mateur, the National Institute for Research in Rural Engineering, Water and Forests, the CBO and the communities and farmers was a key factor in the success of the project and its sustainability.

The great potential recognized so far at this pilot site has boosted the aim to outscale this system to other areas within Tunisia in order to improve the livelihoods of smallholder farmers. As such, this pilot site would be an example for other places within Tunisia and in the Near East region.

For more information

Project final report (Louhaichi *et al*., 2019).

Using native drought-tolerant forage species for enhanced dryland pasture restoration (Blog) by Mounir Louaichi (2021).

Assessment of soil surface scarification and reseeding with sulla (*Hedysarum coronarium* L.) of degraded Mediterranean semiarid rangelands (Slim *et al*., 2021).

Managing rangelands: promoting sustainable legume species: Hedysarum coronarium L.: a biennial herbaceous legume used for forage in the Mediterranean basin (Louhaichi, Slim and Gouider, 2018).

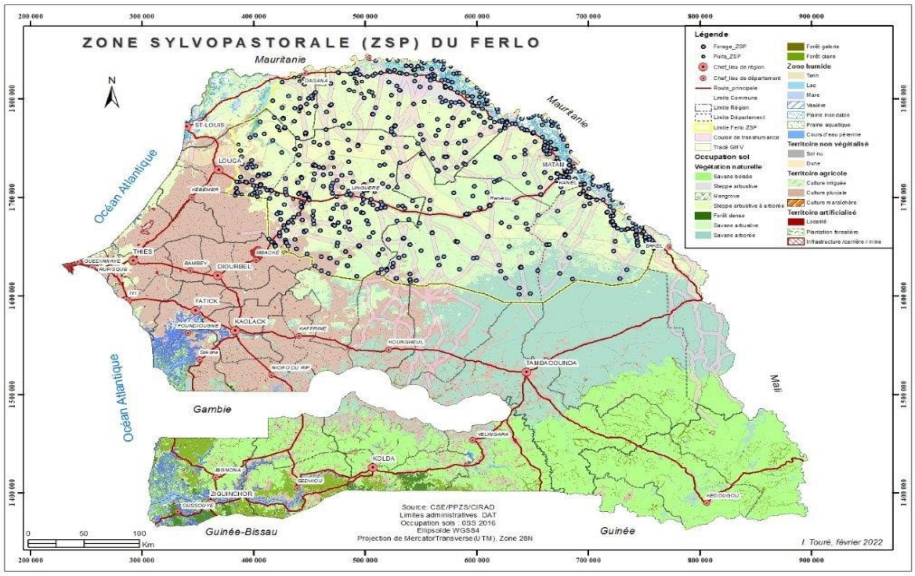
CASE STUDY 7: SILVOPASTORAL SYSTEMS AND SUSTAINABILITY OF SAHELIAN SOCIOECOSYSTEMS IN SENEGAL

The area of Northern Senegal known as the Ferlo, which is dominated by semiarid open rangelands with mainly annual grass and open tree-shrub covers, with a mean annual rainfall ranging from 400 mm/y to 200 mm/y, hosts a large part of the domestic ruminant population (54 percent of cattle (over 3 668 000), 59 percent of sheep (upwards of 7 152 000), and 56 percent of goats (over 6 052 000). Livestock is managed through traditional silvopastoral mobile livestock systems.

Grazing livestock, forests and trees in the Ferlo in Senegal

Landscape in the Ferlo region is composed of undulating smooth sandy dunes in the western part and a ferruginous plateau in the eastern part. The vegetation is characterized by semiarid open tree and shrub steppes dominated by annual grasses (*Aristida* spp., *Cenchrus* spp., *Schoenefeldia gracilis* Kunth., *Panicum* spp., *Brachiaria* spp., etc.) (Figure 10). Dominant tree and shrub species are *Balanites aegyptiaca*, *Boscia senegalensis*, *Senegalia senegal* (L.) Britton, *Vachellia tortilis*, *Vachellia nilotica* (L.) P.J.H.Hurter and Mabb., *Pterocarpus lucens* Lepr. ex Guill. and Perr., *Adansonia digitata* L., *Sclerocarya birrea*, and so on. The average tree and shrub cover is around 15 percent. Due to low and unpredictable rainfall, cropping activities are not dominant in the southern part of the region and are almost absent in the northern part. Silvopastoral systems are the dominant land use, consisting of communal land owned by the government and managed by the local population through the status and regulations of "pastoral units".

FIGURE 10
Silvopastoral zones in the Ferlo, Senegal



Source: PPZS/CSE/CIRAD, I.Touré (2012)

The mobility of the herd and part of the family can vary from 5–10 km to 15–25 km per day in the rainy season, and a total distance of over 300 km during the dry season, depending on the livestock production system and the availability of annual pasture around watering points. In a normal year, cattle are often limited to the boreholes of the northern Ferlo, while small ruminants move increasingly south. Various studies conducted in the area have shown a significant increase in the domestic ruminant population over the past few decades (Touré *et al.*, 2012) and a decrease in the population of some woody species (Dendoncker and Vincke, 2020). Transhumant herders show a preference for routes that allow them to reach the host area as quickly as possible, under good feeding conditions for their livestock (presence and quality of pasture, availability of water, crop residues in agricultural areas) and considering the terms of trade practised in livestock markets (Garba *et al* 2012). The transhumance movements are thus made up of a series of stages carefully chosen based on information collected from informants and the personal experience of the herder.

There is no clear evidence of the impact of livestock on woody vegetation population numbers, despite the fact that tree and shrub leaves and fruits may contribute to 20 and 80 percent of cattle and small ruminant diet, respectively, during the hot dry season when grasses are dry and rare. Among the 27 woody species mentioned by herders as used for food, fodder, firewood, construction, medicine and veterinary support, ten were cited as a source of fodder (Dendoncker, Ngom and Vincke, 2015). As another example, results from a field inventory carried at varying distances from boreholes do not show a significant influence of livestock on woody vegetation density, cover and species composition (Dendoncker and

Vincke, 2020). Many attempts to improve and restore the woody population have been conducted in the area for decades with some positive results. The Great Green Wall for the Sahara and Sahel Initiative (GGW) has been operative in the area (around 10 000 hectares of afforestation since 2011), with FAO supporting processes related to the resilience of rural communities in the implementation of land restoration through the GGW programme between 2015 and 2019 (Sacande, Parfondry and Ciciatello, 2020). More than 200 plant species have been identified as useful to communities, including at least 86 tree species, mainly for human consumption (food, medicine, etc.) and fodder (Sacande and Parfondry, 2018). After a first phase when the population was not so much involved in restoration actions, the new strategy for the coming decades offers the opportunity for local stakeholders to participate in planning and operating restoration activities. Another important issue in the Ferlo is the recent development (starting 15 years ago) of local dairy value chains based on the small dairy industry collecting milk from silvopastoral livestock systems and selling products to urban centres (Corniaux, Duteurtre and Broutin, 2014; Bourgouin *et al*., 2019). This dynamic has the triple impact of improving income and livelihoods for pastoralists (Wane, Cadilhon and Yauck, 2017), offering local products to consumers versus imported dairy products (e.g. full milk powder) and stimulating silvopastoral ecosystem management and valuing through multistakeholder process and planning.

The Ferlo in Senegal: Protected areas managed by pastoralist associations

The Ferlo comprises seven silvopastoral protected areas with old boreholes managed by pastoralist associations to provide water to livestock and human populations (Cesaro, Magrin and Ninot, 2010; Touré *et al.*, 2012). The government has developed several public policies to promote the sustainable management of these protected areas and support livestock mobility. For many decades, numerous development and research projects conducted in this area through collaboration between the Government, CSOs (such as the *Association pour la Promotion de l'Élevage au Sahel* or the *Réseau Billital Maroobè*) and national and international research organizations pointed to an abundance of positive interactions between livestock activities and woody population management (ecosystem maintenance, feeding ruminants, biodiversity management, nutrient cycling, carbon balance, etc.) (Ickowicz and Mbaye 2001; Assouma *et al.*, 2019; Bakhoum *et al.*, 2020).

Most recent results and synthesis of these past and present projects show that there is no clear evidence of the overarching impact of anthropogenic factors over climatic factors on tree and shrub population decrease and ecosystem degradation (Diouf 2002; Diouf *et al.*, 2005; Assouma *et al.*, 2019). While a decline in tree density was observed between 1965 and 2008 (14.8 trees/ha to 11.9 trees/ha; shrubs not taken into account), the following decade was marked by stabilization (12.2 trees/ha in 2018). Over the same initial period, species composition shifted, with a decrease of some tree species (e.g. *Sclerocarya birrea* (A.Rich.) Hochst. *Combretum glutinosum* Perr. ex DC.) and an increase or stabilization of shrub

species and/or drought-resistant species (e.g. *Vachellia tortilis* (Forssk.) Galasso and Banfi, *Boscia senegalensis* Lam., *Balanites aegyptiaca* (L.) Delile). As a result, the shrub-to-tree ratio increased (Dendoncker *et al.,* 2020). A recent study on the carbon balance in silvopastoral ecosystems in the Ferlo showed that these systems are neutral, compensating emissions with storage, mainly due to positive interactions between ligneous plant species, soils and livestock (Assouma *et al.,* 2019). This shows that Sahelian silvopastoral systems are well adapted to their environment and can contribute to sustainable development and food systems when relevant public policies and sustainable rural practices are adopted.

Baseline data is crucial to strengthen the monitoring systems

The project: "Carbon sequestration and greenhouse gas emissions in (agro) silvopastoral ecosystems in the Sahelian CILSS States (CaSSECS)" which spans from 2020 to 2023 aims at improving the assessment of the carbon footprint of Sahelian agrosilvopastoral ecosystems to better quantify their impacts on climate change for the development of livestock policies adapted to the Sahel.

At the end of the second year of implementation, the project already mobilized numerous devices that allow for the acquisition of reference data that will, thereafter, offer the possibility of establishing a carbon footprint adapted to Sahelian silvopastoral zones. At the animal level, use of: (i) green feed to measure methane emissions during ingestion; (ii) experimentation in fields and on stations to evaluate the level of ingestion of ruminants; (iii) near-infrared spectrometers to estimate the chemical composition of animal feces, feeds and forages, using specific prediction equations; and (iv) GPS tags and collars to follow the demography of the herds and their mobility.

For herbaceous vegetation, biomass evaluation is conducted at the plot level, followed by the calibration of drones for a larger-scale evaluation of grass growth.

At the woody vegetation level, use of: (i) root and trunk growth monitoring system to assess the carbon accumulation and intra-annual variation; (ii) canopies growth and dynamics of trees monitored using drones but also terrestrial Lidar calibrated imagery; and (iii) experimentation in the field to study the dynamics of woody communities and their dendrometric characteristics.

For soil and gas exchange: (i) two GHG flux towers measure daily GHG fluxes; (ii) coupled climatological towers monitor weather conditions (data available for the past few years); (iii) automatic and manual chambers calculate soil gas exchange on bare or covered soil, under trees or in open areas; and (iv) soil samples, collected from different territories and according to various grazing management, are analysed in the laboratory to estimate their carbon stock.

In order to fully meet the objectives of the project and to incorporate target people, studies were conducted to understand the choices and practices of pastoralists but also the dynamics of the territories around silvopastoral systems. At the territorial level, the role of trees is linked to ES provision. A study conducted in CaSSECS is based on a better understanding of the socioeconomic importance of tree resources for pastoral households (human food, fruit marketing, animal

feed, construction, energy, local medicine, etc.). The issue ahead is whether the increase in tree density (a GGW objective), possibly with multispecies composition close to natural distribution, is compatible with pastoral livestock farming or whether a compromise must be found between the two activities. The idea is to co-conceive new livestock practices to increase ES and livelihoods while promoting an adaptation of grazing systems to climate change.

Finally, training on using the different devices and methods was provided during these first two years. This training aimed to strengthen the capacities of the project's technicians, researchers and Ph.D. students to facilitate the creation of references. For the next two years, training sessions will be organized for pastoralists and farmers' organizations, as well as for technicians and agents of the ministries, to make the references and tools designed accessible to those who need them.

Management is crucial to managing the positive and negative interaction between grazing livestock and restoring woodland

The analysis of this case, based on the conceptual framework (Figure 3) and the proposed criteria (Table 3), shows that the Ferlo region is quite representative of the general context all over the Sahelian region. CaSSECS has already promoted the acquisition of reference data that will, thereafter, offer the possibility of establishing a carbon footprint adapted to Sahelian silvopastoral zones. The methods used in CaSSECS focus mainly on producing evidence and reliable figures on the impact of the silvopastoral system on climate change and carbon balance. Initial assessment and studies through predictive models and field studies showed that Sahelian silvopastoral systems are significantly under the initial estimates of UNCCC and closer to a neutral GHG balance. This is due mainly to carbon storage in soils and trees and to lower GHG emissions by ruminants with a low annual average intake rate. But pathways to an ecological intensification of silvopastoral production maintaining a neutral carbon balance require a number of preconditions, including: innovative and fine-tuned agricultural practices with real measurement of carbon storage and GHG emissions (ruminant feeding, herd management, etc.); support from governments through appropriate regulations (land-use, proper carbon balance assessment system; import taxes; local value chain support; and investments (communication, rural infrastructure, etc.).

The focus on positive environmental interactions between livestock and silvopastoral ecosystems, without neglecting economic and social aspects and looking at management and policy support and strategy, offers the opportunity to foster multistakeholder discussions on the sustainable development of silvopastoral landscapes and to innovate towards relevant sustainable practices. Co-building and the promotion of innovative practices, regulations and policies that allow positive interactions to be supported between livestock and forestry activities in the Sahel to meet the Sustainable Development Goals (SDGs), while avoiding the negatives, are among the main objectives of CaSSECS project in the Ferlo, together with many other projects taking place in this area.

Livestock, trees and shrubs, grasses, soils and pastoralists are part of the Sahelian silvopastoral socioecosystem which for centuries has demonstrated its capacity to adapt to changes (climatic, social, and economic) in a relatively sustainable way, albeit with negative impacts in specific contexts. Recent studies on ecosystem maintenance, feeding ruminants, biodiversity management, nutrient cycling, Carbon balance (Ickowicz et Mbaye 2001, Danthu et al. 1996, Manlay et al. 2004, Chirat et al. 2014, Traore et al. 2016, Assouma et al. 2019, Bakhoum et al. 2020, Traore 2021) have described more accurately how positive and negative interactions can occur between these components. They showed also that to adapt better to a changing environment and remain in line with SDGs, the project needs to promote practices, regulations and policies that take into account all the components together and to have a holistic, multidisciplinary and multisectoral approach to elaborating new and innovative sustainable solutions and options. Livestock and forestry stakeholders, who are the main actors in this environment, must then collaborate and be open to other actors to design the operational context, Accordingly, the institutional and political environment for the sustainable management of the Sahelian region would be strengthened to take action against desertification impacts.

For more information
www.cassecs.org
www.ppzs.org

CASE STUDY 8: FOREST OWNERS AND LIVESTOCK FARMERS DETERMINE THE SUCCESS OF SILVOPASTORALISM IN NORTHEASTERN SPAIN

Aragon (Guara Natural Park) and Catalonia (Lluçanès County) in the northeastern part of Spain display important differences arising from the forest property regimes. In Guara, 40 percent of the forest land is forest commons belonging to municipalities (regional government), while in Lluçanès, more than 90 percent of the forest belongs to private forest owners and 50 percent of the forest land, that is, around 24 000 ha, has a forest management plan. Around 400 of these private forests are bigger than 10 ha and around 200 forest owners hold forest states bigger than 50 ha. A shift from sheep to cattle farming has taken place in both areas. The overall stocking rate in forest land is low due to the reduced quality of forage in forest land. Supplementary feeding is provided by cattle farmers. In the absence of management optimization, this causes an irregular distribution of stocking rates with areas under high grazing pressure while others remain unexplored.

Silvopastoralism as an adaptation strategy for an integrated rural development

Extensive livestock farming and silviculture have experienced a significant decline in the rural areas in Spain, triggering unwanted effects on ecosystems and society. The reduction in forest management has resulted in an increase in biomass and

vulnerability to wildfires jointly with habitat loss. The decrease in the number of farms and livestock (especially sheep) is linked to the decline of farming revenues and the income gap in rural areas classified as non-disadvantaged, which explains the scarcity of generational change. Frequently, these farms are located in high natural value areas, providing a broad array of ES.

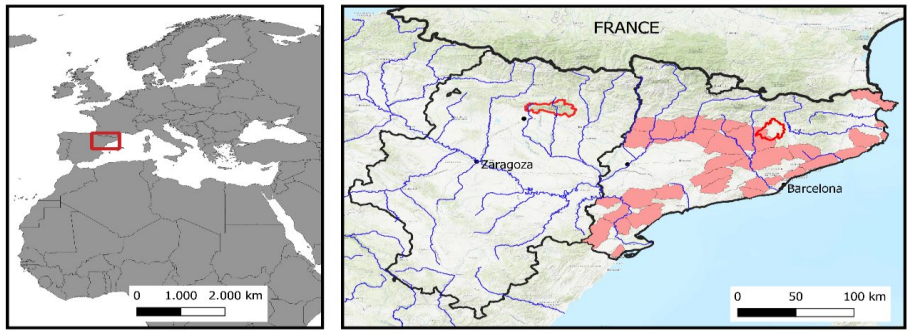
Forest grazing provides a strategic resource in times of scarcity (Casals *et al*., 2009), contributing to self-sufficiency objectives (Varela *et al*., 2022). Taüll (2009) found out that in half of forest states with a forest management plan, the pastoral objective is proposed either as the main or secondary objective. However, the pastoral management of these states is not detailed in the planning (i.e. pastoral calendars, stocking rates or productivity of pastoral resources are usually missing in these plans). This makes forest pastures less attractive although they may become a valuable resource for landless grazers. However, the increased labour requirements of forest grazing, the fragmentation of small properties coexisting together and the mix of public and private lands along with the lack of water points and shrub encroachment, hinder forest grazing. Innovative public and private initiatives have flourished to promote silvopastoralism as a tool to reduce vulnerability to wildfires in Catalonia and other regions in Spain.

Behaviours, attitudes and practices impact the silvopastoralism

Silvopastoralism as an adaptation strategy for integrated rural development in the Mediterranean project was initiated by the Institute of Agrifood Research and Technology and the University of Zaragoza, in Lluçanès region, Catalonia and Sierra de Guara Natural Park, Aragon in Spain. The main assumption underlying the whole project is that greater integration between forestry and livestock grazing would benefit both activities. Thus, the project assessed the factors contributing to or hindering the collaboration between forest owners and livestock farmers, hence reducing vulnerability while providing the services that society expects from those lands (Figure 10).

The project team explored the attitudes and opinions of forest owners and livestock farmers regarding various dimensions of silvopastoral management and analysed whether those were linked to their structural characteristics and management objectives. The project team interviewed a total of 19 livestock farmers and 21 forest owners. The team was thus able to determine which profiles were more likely to engage in joint silvopastoral activities and hence contribute towards improving the sustainability and provision of ES in Mediterranean forests. Furthermore, the team analysed the contribution of silvopastoral management practices (SMP) to the provision of ES. Silvicultural treatments exhibited a multifunctional role, improving ES in bundles (provisioning and cultural ES and wildfire prevention). The study also involved regional and local administrations and technicians through in-depth interviews and workshops to discuss the integration between forest management and livestock grazing.

FIGURE 10:
Location of the study area in Spain (left) and the Guara Natural Park in Aragon and the priority protection perimeters for wildfire prevention in Lluçanès county, Catalonia (right).



Analysis of different attitudes on the role of grazing in managing and restoring woody dryland in the project area

Using semistructured questionnaires and closed questionnaires, face-to-face interviews were conducted respectively with local experts and with forest owners and pastoralists. The team applied the structured expert consultation Delphi method to assess the medium-term effect of 18 SMP on the delivery of eight ES in Mediterranean mid-mountain silvopastoral systems. 69 experts were asked to assess the positive mid-term (five-ten years) and rational use (mid-intensity) effect of each SMP over each ES at stand level in the selected combinations through a six-point Likert-type scale from none (0) to very high positive (5) contribution. The rational or moderate use of each practice (mid-intensity) is to modulate the potential negative impact of over application of some of the practices (e.g. clearing).

As shown in Figure 11, the most positive synergies were found between forest owners and cattle farmers, as already signaled by Taüll *et al.*, (2009). Farmers expressed a positive attitude towards wood pastures because of their positive economic impacts and their strategic role in periods of shortage of other resources. Grazing of wood pastures contributes to self-sufficiency in farm feed, a key element for farm sustainability.

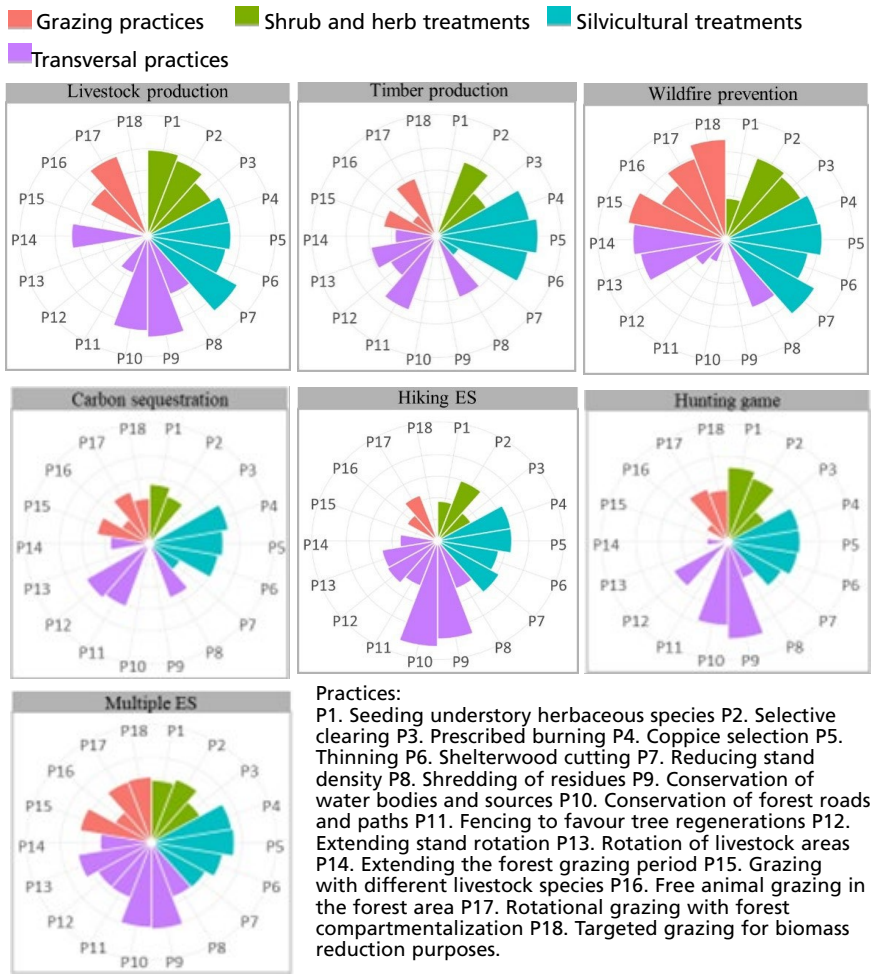
Simultaneously, they were aware of the low stocking rate allowed by these pastures in order to make sustainable use of them. Owners of small forests acknowledged the environmental functions of grazing to a greater extent and were significantly more interested in subsidies for grazing than owners of larger forests. The dimensions of mobility and accessibility offered by grazing were acknowledged by owners prioritizing wildfire protection objectives. Importantly, this wildfire protection role is frequently valued over the financial return of the pastoral activity (Taüll *et al.*, 2009). Acknowledgement of the role of grazing in landscape maintenance was positively correlated with several objectives held by forest owners, from economic productivity to the more altruistic.

Livestock production, habitats for biodiversity and wildfire prevention were the ES provided to a higher extent by the overall SMP evaluated. The SMP with the highest contribution to livestock production was reducing stand density,

the conservation of water sources and the conservation of forest roads. Among grazing practices, their results indicate that grazing management regimes with more animal control, such as rotational grazing or target grazing can be more effective in meeting multiple management objectives. The type of livestock (small ruminants vs. cattle/horse) also influences the achievement of these objectives. Neither of the SMP evaluated simultaneously maximized its contribution to all ES. Nevertheless, silvicultural treatments and transversal practices (e.g. conservation of water bodies and shredding of forest residues) provided multiple ES bundles, suggesting the importance of properly managing tree cover for the delivery of ES. Multiple synergies arose among provisioning, regulating and cultural ES whereas trade-offs were especially important between erosion control and wildfire prevention.

FIGURE 11:

Rose diagram illustrating the contribution of SMP to individual and multiple ES. Each petal of the rose represents the contribution (from 0 or null to 5 or very positive) of the practice on the ES while the colour refers to the management practice domain.



Practices:
P1. Seeding understory herbaceous species P2. Selective clearing P3. Prescribed burning P4. Coppice selection P5. Thinning P6. Shelterwood cutting P7. Reducing stand density P8. Shredding of residues P9. Conservation of water bodies and sources P10. Conservation of forest roads and paths P11. Fencing to favour tree regenerations P12. Extending stand rotation P13. Rotation of livestock areas P14. Extending the forest grazing period P15. Grazing with different livestock species P16. Free animal grazing in the forest area P17. Rotational grazing with forest compartmentalization P18. Targeted grazing for biomass reduction purposes.

Silvopastoralism can be a win-win activity for both forest owners and farmers

In-depth analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that silvicultural and livestock management practices can contribute to the delivery of bundles of ES including the positive acknowledgement of the role of grazing in landscape maintenance and identifying the trade-offs between SMP, e.g. free animal grazing can reduce grassland biodiversity.

However, there are also potential challenges in bringing these forest owners together and integrating private (or public) land ownership with the right to graze the same place. The role of public administration is crucial for establishing the framework and rules that determine who bears the costs of the different interventions, which after all are aimed at providing benefits for farmers, forest owners and society. Compensation strategies can be designed to reward those involved with wood pasture grazing for the potential compromises they may make when pursuing certain management objectives.

This case demonstrated that SMP drive the provision of a high number of ES in a synergic manner, revealing great potential for Mediterranean forests to improve their multifunctionality and support extensive livestock farming systems through better integration of both. However, the decline of SPS in the Mediterranean and the increasing application of SMP with a low multifunctional character (e.g. free animal grazing) could possibly lead to negative contributions to some ES. Hence appropriate measures would be needed to encourage SMP that lead to optimizing the provision of ES bundles, or a single ES when needed, accounting for the trade-offs implied. The SMP study revealed multiple synergies in the overall provision of ES, reinforcing the role of SPS to reconcile production and conservation while increasing resilience in the face of climate change to ensure sustainable ES delivery.

The most adequate silvicultural management practices should be determined by jointly considering management objectives, pasture type and farm systems in the area, to develop win-win scenarios for forestry, livestock farming and ecosystem service provision.

For more information

Plataforma por la ganadería extensiva y el pastoralismo,, Ramats the foc, grazing to prevent wildfires, cuadernos SECF, LIFE Montserrat, Espais Test, Alberapastur.

CASE STUDY 9: RANGELAND FORESTS AND SILVOPASTORALISM IN UZBEKISTAN'S COLD DESERTS

Irregular forest cover in Uzbekistan accounts for over 3.5 million ha – about 7.7 percent of its land. Desert-like forests are the most abundant, (approx. 81 percent). Mountain forests (12 percent) are on the slopes of Western Tien Shan, while the remainder – the Tugai valley forests – extends in narrow belts along the main watercourses. All existing and newly established forests in Uzbekistan have

protective and land reclamation values. The State Forestry Committee handles some of these areas, while others are managed locally. Land use in Uzbekistan is usually as rangelands, which occupy over half the country's surface. They are especially abundant in the arid desert-like drylands, but they also occupy over 15 percent of foothills and plains, close to the agricultural nodes. Rangelands are key assets for the livelihoods of rural and poor pastoral communities in the country, who depend on grazing livestock for food, income and other key resources like fuel and herbs.

Grazing livestock, forests and trees under threat in Uzbekistan

Uzbekistani forests and rangelands are facing a severe process of degradation caused by population growth, uncontrolled harvesting of wood and non-wood productions, encroachment, expansion of agricultural lands, change in water regimes, increasing stocks of livestock grazing in forests, and climate change. Overgrazing is linked to the breakdown of the Soviet fodder provision system and the reduction of livestock mobility. This caused a serious imbalance in the use of fodder resources, which led to severe overgrazing in key pastures and underuse of others. Land degradation speeds up with overexploitation of other resources, failure in land management, lack of security in land rights, weakness in governance institutions, abandonment, industrialization of agriculture and urbanization, among other things. This scenario has become catastrophic for the Aral Sea. Climate change, extreme weather events such as droughts and decreasing precipitation are also key drivers. They contribute to degradation, reducing water reserves and availability and deteriorating production. Groundwater level and recovery capacity are decreasing. The use of water reserves is much larger than the natural recovery capacity. Water scarcity is the cornerstone of production activity in those lands, affecting rainfed crops and concentrating livestock around water points, which is also heavily degrading the surroundings of the wells.

Pastoralists and other livestock producers are struggling with scarce resources. They adapt their herd size to survival, keeping small multispecies flocks of 3–5 cattle and/or 3–6 sheep and goats in a subsistence model. Bigger flocks would be difficult to raise under those conditions, while smaller ones will not be enough for the household to make a living. Smallholders use monthly grazing tickets to rent state rangelands for the nine-month grazing season. These temporary rental agreements are fragile, while grazing areas are limited and fees can be high at the district level. Increased labour migration from rural areas to cities or other countries is also limiting the traditional management and mobility of flocks and making access to remote pasturelands difficult and sporadic. Other traditional pastoralist strategies, such as pooling, are also increasingly difficult under the current economic situation. All these factors contribute to generating a complicated scenario where it is increasingly difficult to keep extensive livestock farming under sustainability parameters.

Reducing the number of livestock versus good management

The diagnostics summarized in the previous sections show that, while major impacts are traced to grazing and harvesting timber and non-timber productions, external trends such as urbanization, industrialization of agriculture, or overuse of water resources, along with the weakness of rights of access and use of the resources are preventing the activity of households and small farmers from behaving more sustainably.

In an initiative to engage local stakeholders in designing innovative actions to preserve the desert ecosystems, the Central Asian Desert Initiative (CADI) – a project supporting the conservation and sustainable use of cold winter deserts in Central Asia funded by the German government within the International Climate Initiative (2017–2022) and developed by the University of Greifswald, and FAO's Subregional Office for Central Asia –conducted several participatory processes to engage local stakeholders. Among those processes, they set the focus on creating farmer field schools for the training and participation of 87 local women and 65 men farmers and smallholders. This way, training and participatory activities, designed in a gender-sensitive way, can empower and prepare local stakeholders to build the knowledge and capacity needed to improve production, maintain ecosystem integrity and reduce the long-term economic risks associated with degradation. Technical actions proposed by the project aim to improve land management, increase productivity and diversify production to reduce pressure on natural resources. Implementing these measures demands a participatory approach whereby local stakeholders should be the main beneficiaries and decision-makers of the actual measures implemented. Women play a key role in the development of these solutions, as they usually manage resources linked to household production, such as livestock raising, harvesting, or fuelwood collection. Thus, a gender-sensitive approach has been deeply integrated into the project, from training to participatory decision-making.

Among the different measures and recommendations implemented under the CADI umbrella, several practices aim to improve the situation of forests and rangelands. Among the forest restoration, the project distributed seeds and more than 10 500 seedlings of tree species to local farmers and smallholders to prevent sandstorms and mobilization of dunes and protective forest belts around factories, roads and pipelines. Rangeland degradation on the other hand is addressed by rotational grazing, redistribution of water sources and wells, reseeding and planting new pastures based on native species tolerant to salinity and water scarcity, improved water harvesting and management, fencing in specific areas and implementation of integrated crop-livestock systems.

Knowledge building and participatory processes led by the project have given rise to several recommendations on how to address small farms and households to improve their products and their outcomes in terms of land management. These recommendations include several measures and small investments designed to improve livelihoods and create jobs and income-generating opportunities for women and men, thus improving the living standards of local communities. These

recommendations address some policy issues on governance, gender balance and security in land tenure. Improved access to water for small farms and livestock is one of the key actions planned, demanding a close look at equity and gender balance. Programmes of small investments are also planned for farmers and households, including diversifying agricultural activity through beekeeping, improved seeds and seedlings for rainfed crops, aromatic plants, and so on. Project investment is being channelled to 120 smallholders to develop a milk processing value chain, support home-based handicrafts and provide small greenhouses to encourage backyard horticulture for local people. Finally, specific training and technical support are being provided to implement those advances while lowering the risks and improving the results in terms of sustainable land management and land degradation neutrality.

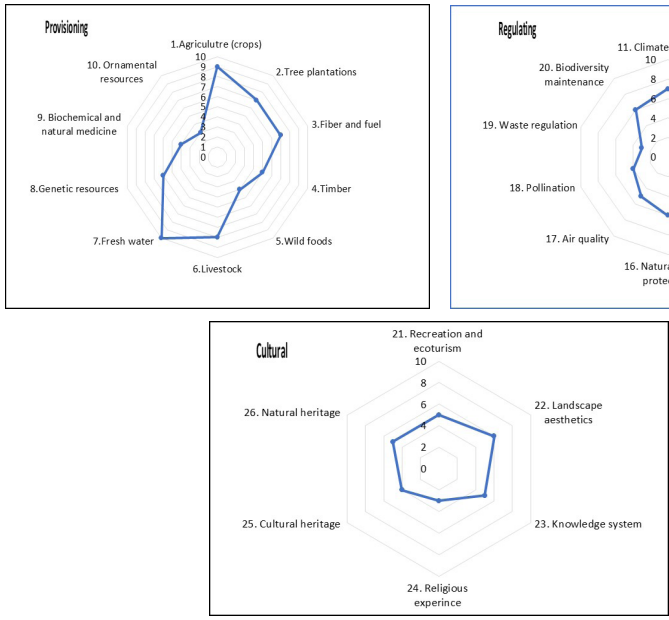
A need for assessment for better planning of ecosystem services

CADI conducted a local assessment of ES in Durmon village in northeast Uzbekistan to understand the reactions of pastoralists and silvopastoralists and make recommendations focused on the role of grazing livestock. The preliminary analysis was based on a survey of 200 randomly selected households to study their baseline condition and analyse their perception of ES (Table 9). The second step was a choice experiment analysis conducted for 300 households to identify their willingness to pay for services (including water supply) of water users to produce crops. The analysis produced the following results, prioritized and graphically displayed on shown in Figure 12.

TABLE 90
List of Durmont village ES delivered by the local assessment

Provisioning ES	Regulating ES	Cultural ES
Agriculture	Climate regulation	Recreation and ecotourism
Tree plantation	Hydrologic regulation	Landscape aesthetic
Fuel and fibre	Water flow and purification	Knowledge system
Timber	Soil retention and erosion control	Religious experience
Wild foods	Pest and disease control	Cultural heritage
Livestock	Natural hazard protection	Natural heritage
Freshwater	Air-quality	
Genetic resources	Pollination of crops	
Biochemical (natural medicine)	Waste regulation	
Ornamental resources	Biodiversity maintenance	

FIGURE 12
Prioritization of ES in Durmon village
(From 0 = Not important to 10 = most important)



Source: Elaborated by case study authors

Agroforestry is the agreed solution

In their search for solutions, the stakeholder consultation and the ES assessment confirmed that agroforestry is an important instrumental to implement the improved land management strategies in the Central Asian Deserts and establish a sustainability framework for grazing livestock in forests and rangeland areas. First, grazing should be planned and organized considering the life cycle of pastures on forests and rangelands, establishing clear grazing and resting periods and stocking rates during the active periods and comparing this with the actual numbers of livestock and grazing regimes. This task should be performed in close collaboration with local producers with intimate knowledge of the phenology and characteristics of their pastures. There may also be additional fodder resources that were not accounted for, such as mountain pastures formerly used by transhumant shepherds, wood crops, fruit trees that could be grazed after harvesting, and so on. Those resources could be integrated with grazing management plans that would fit the load capacity of the different patches of land (Table 10). Additional grazing resources can be found using forest leaves as fodder, or grazing in stubble and fallows, which allow for crop integration and livestock activity. Recovering rotation in crops and using fodder crops and harvest residues to feed the animals during pasture resting season could also contribute to pressure release over woods and rangelands. The underlying conditions for developing ideas around pastoral mobility must be fully functional to access diverse sources and there should be a better distribution of water points for livestock.

TABLE10
Best practices for improving land degradation and food security in the cold winter deserts

	Issue to be addressed	Interventions
1	Water shortage/ scarcity	Application of Integrated water management system, designing and implementation of demand-driven and carefully targeted irrigation schemes
2	Rangeland degradation	Controlled grazing, shrub plantation, water harvesting for animal drinking and plantations and protected natural rangeland
3	Overgrazed pastureland	Establishment of protected areas to reverse degradation
4	Limited capacity rangeland	Rotational grazing plan
5	Fodder scarcity	Additional biomass production by replacing annual forage crops with forage and cover crops rotation
5	Degraded soil health	Planting salt and drought-tolerant improved varieties and the improved seed of leguminous food and fodder crops

Analysis based on the conceptual framework (Figure 3) and proposed criteria (Table 3) shows that integrating forests and rangelands under sound grazing management plans is a challenge for dryland forests in Uzbekistan, already under heavy pressure. This could complement plans for water management strategies in the field, increasing retention and water harvesting, building wells to distribute water points and reducing concentration and land degradation in their surroundings. Planting fodder crops around wells could reduce pressure over local rangelands. Use of leaves from trees and shrubs could also complement animal feed during drought times, mobilizing alternative feed sources from crop residues.

Planting trees and shrubs with potential use as fodder is another strategy to restore forests and drylands, although this requires proper management to synchronize grazing with the development of saplings and seedlings, avoiding early degradation. Enclosures could be another strategy to restore key woody vegetation in areas where they could become key assets during drought times and to contribute to fertilizing key spots (such as home gardens). Diversification is also an adaptation strategy. Besides some alternatives and small investments already started by the project, a silvopastoral approach could be of help in this area. For instance, using small ruminants to graze and maintain orchards, fruit trees and vineyards, and maintaining woody fences and edges separating various kinds of land. The farmer field school approach helped to educate local farmers and smallholders on improved wheat and chickpea production, leading to higher yields and incomes.

For more information

CADI website: https://cadi.uni-greifswald.de/en/home/

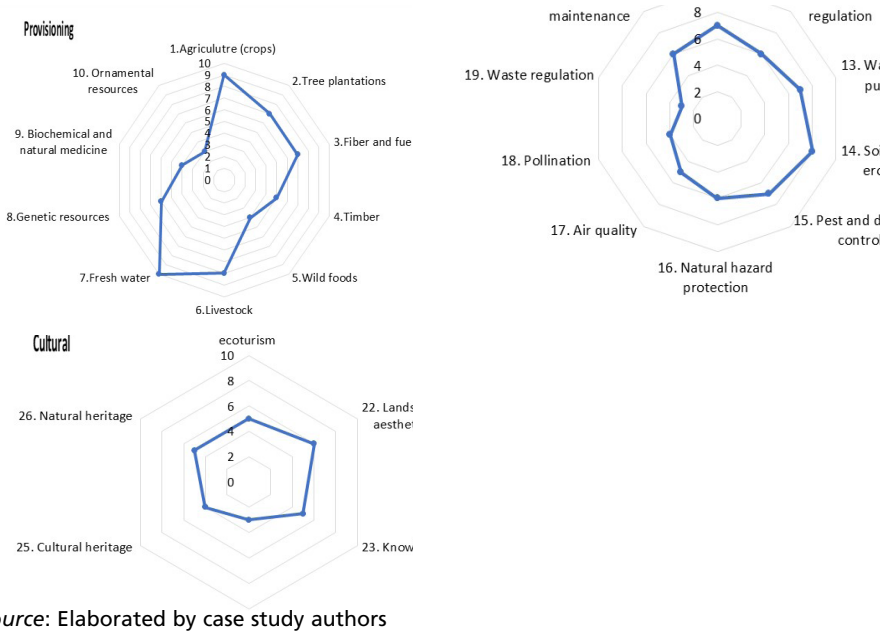
Report: Integrated natural resources management worldwide and in Uzbekistan.

CASE STUDY 10: RATIONAL GRAZING ON BOCAGE PERIMETER IN BURKINA FASO

In Burkina Faso, the farming system commonly practised is often considered one of the main causes of land degradation. The rural populations of these areas are agrosilvopastoralists. Family members (grandparents, their children and their wives and grandsons) live together, using both common and individual lands, which they clear for agriculture, and herding their own livestock in an open and free-range system, in which livestock are left to permanently wander seeking for

FIGURE 12

Prioritization of ES in Durmon village (From 0 = Not important to 10 = most important)



Source: Elaborated by case study authors

food. Consequently, grasslands are frequently overgrazed and animals are often responsible for destroying crops and younger trees, leading to production losses and conflicts between livestock producers, farmers and woodland owners. At the pastoral level, some grass species could be disappearing and grasslands will be reduced. Land degradation includes strong deforestation of the woody ecosystem due to low rainfall and prolonged droughts, overexploitation and bush fires, which keep contributing to soil degradation and a drop in rainfall. The degradation and deforestation of local landscapes also have a negative impact on local communities, leading to heavy losses in agriculture and silvicultural productivity. Consequently, food insecurity and poverty are increasing. Women are especially affected by this phenomenon. In fact, as they usually increase their household incomes through the sale of non-timber forest products and milk, the economic impact is harder on them, contributing to inequality. Other people, such as livestock breeders, are also affected as they often need to buy additional feed on the market, increasing production costs.

To fight against this problem, local populations are developing different ideas to cope with the situation, such as reforestation initiatives, stone lines and gabions, and restoring the degraded lands. This scenario also triggered the foundation of the bocage perimeter project.

A bocage perimeter for grazing livestock with trees

A bocage perimeter is an integrated system that combines trees, animals and crops. In Burkina Faso, perimeters are requested by landowners but built, by pilot farms, for the whole community, with different responsibilities distributed among owners and livestock producers. Each owner manages four fields of 0.62 ha, each one with a dug pond where livestock are watered. A rational grazing system including trees is one of the key parts of the system. Its goal is to provide grass in enough quantity and quality, but also to increase the productivity of trees and to help with ecosystem restoration. Rational grazing on bocage perimeter has been implemented in the semiarid areas (plateau central and Centre-Nord regions where the level of rain is between 600 and 900 mm per year, concentrated in 3 months) and in the arid area (the Nord region, where the amount of rain is less than 600 mm per year). Vegetation in the northern regions is characterized by steppe rangelands, while the central plateau and Centre-Nord regions are mostly occupied by savannahs. However, these lands are facing strong deforestation and increasing degradation. According to the 2019 study report of the Forest Investment Programme, the country is losing 243 450 hectares of forest per year. Deforestation and degradation are driven by agricultural expansion, overgrazing, bush fires, and excessive cutting of wood for energy and charcoal production, as well as mining and climate change.

Developing a sustainable grazing model in open lands is quite difficult

The effects of grazing in arid lands are variable and controversial; the related impacts can be serious, depending on the type of grazing, the animal load and the time of the year. In order to reduce these impacts the project is thus experimenting with the implementation of rational grazing on the bocage perimeter as a key management system for both the livestock and the mosaic of land uses providing feed for them. Since 1989, the NGO "Terre Verte" has been helping in resolving the conflicts between owners of wooded lands and livestock breeders through the bocage perimeter project and technically and financially providing a pilot farm created by a local intervillage association to develop bocage perimeters and wooded roads. A bocage perimeter is a set of fields protected by a network of fences and vegetal hedges, with each field delimited by bunds and hedges. At the lowest corner, a pond is dug to collect the rainfall and supply groundwater. In the middle and border of the field, trees are planted to complement the system.

The pilot farm develops bocage perimeters and provides landowners and farmers with management training. Additionally, producers have also been trained in agrosilvopastoralist tools and good practices. Rational grazing is promoted in this training programme as a powerful technique for improving pasture management.

Rational grazing aims to restore both forests and pastures and also to supply grass in quantity and quality to feed livestock. Terre Verte is using rational grazing to build a new landscape approach, integrating trees, grazing and livestock. This integrated system provides the farmers in a bocage perimeter with additional productions, both timber and non-timber products to complement agriculture and husbandry.

The existence of national, regional and subregional markets for these products and the technical support provided by research centres have improved the opportunities for developing agrosilvopastoralism in bocage perimeters, which are becoming more profitable and creating jobs for the rural population.

Challenges and opportunities of rational grazing in bocage perimeters

The implementation of rational grazing in arid areas turns out to be a challenge, as it implies setting rules for grazing that may clash with other activities (free-range or wood cutting). The bocage perimeters can contribute to solving this problem by creating protected areas where grazing lands are more controlled. It also permits the protection of trees from browsing animals and excessive logging. Additionally, rainwater is kept in the field, making the soil of the trees moister along with the trees themselves. The water is also used for watering cattle and the whole cycle is improved. When rational grazing is practised in fallow land, it also supplies the soil with nutrients in short term and improves land restoration in the long term.

Concerning the rules of grazing, each year the bocage breeders helped by the pilot farm ask permission from the owners to graze their animals. The pilot farm advises on the timeline, establishing the correct time to start and end grazing and transmitting this information to both owners and breeders' groups. Outside of these periods, free-range wandering and grazing in the perimeter are forbidden. The grazing season generally starts in mid-June and lasts until the end of September. At that moment breeders mow the grass and store it for the dry season. This treatment also allows grass to grow and disperse seeds that germinate and recover the vegetation in the next rainy season and the seed bank to grow.

Rational grazing in bocage perimeters is practised in both rainy and dry seasons. During the rainy season, rational grazing is practised in the fallow fields, thanks to the crop rotation system. Every year, one field is left fallow and available for grazing by each farmer, rotating the next year. These fallow fields are grazed by the animals of bocage breeders providing their feed. The fallow field to be grazed is divided into small areas according to the number of animals and the amount of grass, using electric fences. Within an area of 750 m², 20 head of cows are allowed to graze each session. The grazing time in a field is short, preventing the animals from consuming the regrowth, which often appears very quickly. This allows the animals to quickly graze the grass and not compact the soil by staying there for a long time (Figure 21).

Rational grazing implies both animal and field rotation every year accelerating the biomass fluxes. Nowadays, rational grazing is implemented in the following villages: Guie, Doanghin, Konkoos-raogo (in total 368 hectares of land developed

as bocages perimeters in the plateau central region); Toegin, Kamse, Goema and Lebda (410 hectares of land developed as bocages perimeters in the Centre-Nord region); and the villages of Barga, Filly and Gourbaré (261 hectares of land developed as bocages perimeters in the Nord region).

Despite these advantages, this type of grazing also shows a negative effect that needs to be addressed: the water points are fixed on the field and leads to compacted soils and grass.

FIGURE 21

The impact of silvopastoralism is measured through observations of the state of grass, animals and trees. The photos below show a portion of space where rational grazing has been practised for a long time and the grass continues to grow back.

Before grazing While grazing After grazing

The rest period (the interval between two successive grazing of cattle) varies from two to three weeks depending on the climatic conditions and the speed of grass regrowth. A resting period of two weeks is applied when the rains are plentiful enough and the grass grows quickly. Water must be sufficient so that the grass can replenish its root reserves for good regrowth, thus preserving the grassy flora.

In the dry season: grass becomes increasingly scarce and its quality decreases. Farmers in the bocage perimeters are advised to leave crop residues in the field for animal grazing. Additionally, the animals supplement their food needs with leaves and fruits from the trees and shrubs. Trees and hedges are also a refuge for biodiversity.

The role of grazing in managing and restoring woody drylands in the project area.

In-depth analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that rational grazing in the bocage perimeter has improved the coexistence of trees and animals and the communities have been able to restore degraded lands. Animals graze in the fields without harming the trees, thanks to the electrical fence, which keeps them in a limited area. This allows trees to grow in better conditions and provide fruits and leaves for people and as additional feed for animals. Tree owners are also satisfied because rational grazing brings nutrients to the soil through animal excrement. Meanwhile, thanks to rational grazing, bocage breeders do not need to go far to graze their

Sectorial agrosilvopastoral policy in Burkina Faso

Burkina Faso's socioeconomic development is largely based on agrosilvopastoral, fishing and wildlife activities. As such, the development of the agrosilvopastoral production sector is a priority for the country's Government. Following the adoption of the National Economic and Social Development Plan (PNDES), the government has undertaken to adopt policies for all planning sectors defined in this national repository including a sectoral policy "Agrosilvopastoral production" (PS-PASP). This policy aims to make agrosilvopastoral production by 2026, a modern, competitive, sustainable sector that drives economic growth, based on efficient family farms and agrosilvopastoral enterprises ensuring all citizens access to the food they need to lead a healthy and active life. The process of developing the PS-PASP favoured the participatory approach with the involvement of all players in the sector. Its implementation will not only be the responsibility of the ministerial departments in connection with the rural world but also to other public and private actors, as well as to the communities of base and development partners. The sector's field of action covers the value chain of agrosilvopastoral, fishery and wildlife products, as well as the services related to these activities.

The PASP sector policy draws its foundations from different national and international tools, from the PNDES and the national plan for sustainable development of the land at the national level, to ECOWAP + 10 (https://www.inter-reseaux.org/wp-content/uploads/bds_no19_ecowap_en.pdf), the African Union's Agenda 2063 or the Sustainable Development Goals.

The overall objective of the policy is to develop an agrosilvopastoral production sector ensuring food security, more market-oriented and creator of decent jobs based on sustainable production and consumption patterns. Ultimately, this will involve halving the proportion of people vulnerable to food and nutritional insecurity, develop an evolving and competitive agrosilvopastoral sector able to create at least 31 200 jobs per year, reduce the incidence of poverty in rural areas below 35 percent, improve the average monetary income and reverse the trend of degradation of natural resources.

animals. Their livestock has access to good-quality grass. Rational grazing has also improved the relationship between breeders, trees and field owners, leading to a decrease in the number of conflicts.

On the environmental side, by planting trees on degraded grazed lands through the bocage perimeter, the NGO Terre Verte contributes to the fight against climate change by increasing carbon sequestration by roots, trees and soil. The association of rational grazing to a bocage perimeter has an overall positive effect. It contributes to restoring landscapes by increasing soil fertilization. Even though grazing has a negative impact on the land by trampling and the risk of grazing the re-growing seedling, the rational grazing system addresses and limits those constraints. When fields are divided into pieces according to the quantity of grass and animals, animals do not trample for a long time and also cannot

graze the regrowth seedlings each year. The previously grazed fields are thus left for new patches, reducing the negative impact on the land. Additionally, rational grazing does not clear the land. Vegetation of a certain height is left untouched to allow the seedlings to re-grow and also to continue slowing down the rainwater flow. A silvopastoral approach combining rational grazing with trees in a bocage perimeter has allowed the return of animal and vegetal biodiversity.

Trees are more respected when growing in a bocage perimeter. The bocage perimeter owners no longer cut down trees without planning. They ask the pilot farms for technical support. The fact that bocage perimeters are situated in common land also dissuades the population from excessive tree cutting. Communication between the different actors has improved, and land is generally better managed.

For more information:

FAO's Family Farming Knowledge Platform. Reclaiming life in marginal areas and fragile ecosystems through innovative solutions: The case of bocage perimeters in Burkina Faso.

WÉGOUBRI, LE BOCAGE SAHELIEN: intégrer la sauvegarde de l'environnement dans l'agriculture sahélienne au Burkina Faso (French).

CASE STUDY 11: CONSERVE NATIVE FLORA THROUGH ECOLOGICAL RESTORATION AT THE ROYAL BOTANIC GARDEN OF JORDAN

Tell Al-Rumman area is a forest site located 25 km north of the capital city Amman and on the north-facing steep slopes overlooking the King Talal reservoir in Jordan. The forest area comprises a significant variety of soils and microclimates, several wadi systems, a perennial freshwater stream and over 300 m of elevation change within its boundaries, which make it important to conserve the native flora of Jordan through ecological restoration, research and conservation action. The Royal Botanic Garden (RBG) site is located in an open, mountainous and degraded forest area, mainly covered by pine, oak, pistachio and carob trees under the management of the Ministry of Agriculture, until the garden project was approved.

Five neighbouring herders with a total number of 1 500 head of local sheep and goats used to graze on shrubs and grasses. Trees were used as shelter in summer and winter and one herder was still transhumant. However, local herders kept illegally grazing their livestock all over the site throughout the entire year. They usually accessed their herds late at night or very early in the morning for grazing and, on many occasions, cut parts of the surrounding fence around the site to allow their herds to enter. This situation presented a huge problem to the RBG management team, especially with their focus on ecological restoration – plant cover, vegetation surveys and making biomass estimates without such uncontrolled interference.

This potentially conflictive scenario demanded a strategic solution to combine conserving the forest flora and satisfying the requirements of the local herders –

offering them a satisfactory outcome and ensuring local community engagement in the solution. In 2008, the RBG became responsible for managing the site and conserving the Jordan Flora native species. Accordingly, the garden started to design a community-based rangeland rehabilitation programme (CBRR) to develop efficient sustainable rangeland management strategies through reviving communities' knowledge with science-based interventions.

A range of scientists and veterinarians were thus engaged to work alongside RBG botanists, landscapers, foresters and the local herding community to design the management and research projects at the heart of the CBRR. Many public meetings with livestock owners and key actors in the area were held to discuss the problem, possible solutions, alternative grazing scenarios and the timing of grazing. These stakeholder dialogues and consultations also fostered cooperation and agreement on a sustainable land management approach. The first steps were patchy and only five local herding families fully cooperated with the CBRR in the first year. However, the benefits quickly became evident to the early joiners and by 2009, livestock owners who once grazed the site to bare soil were policing themselves and teaching others. The number of herding families participating has been growing steadily since then, rising to 54 families by the year 2018.

Programming the community–science interface at the RBG site

The design and co-building of the site management system were performed through a participatory process involving the RGB team and the local herding community. Moreover, the CBRR project has conducted many research studies (with the participation of local herders) to secure the scientific data necessary to improve decision-making related to the grazing management system within the RBG site. To build community ownership and accountability, the CBRR considered several complementary activities such as capacity building, training sessions and knowledge-sharing, designed to organize access to and use of the RBG site, schedule the stocking rates and define the grazing scenarios for local producers. Herders who habitually grazed on the RBG site were at first offered replacement forage in exchange for the removal of grazing while vegetation surveys and biomass estimates were conducted; the site was divided into 11 rangeland sectors and the grazing system was designed. The grazing management system then granted access to these herders during late summer and early autumn, for periods collaboratively determined according to the biomass and stocking rate studies. According to this schedule, herders are permitted to enter specified sectors through RBG service gates, and only sheep herds are allowed to graze. 750 head of sheep were allowed to graze on the site for a period of four months for 2.5 hours twice a day, which is considered enough for sheep to feel full. After the determined period ends, the herds move to other sectors following the schedule. The CBRR team supervises the grazing on the site every day and evaluates the vegetation and biomass of the grazed sector. During the grazing period, when the herds graze in the lower plain areas of the site, the herders usually water their livestock from the dam, and when grazing in upper mountainous areas, the herders

bring their water tanks to specific points for watering the herds.

Other beneficial activities are related to the practical training and advice to the community, pastoralist-related issues such as animal health, hygiene and herd management techniques and facilitating access to veterinary care. Local women played a significant role in supporting the CBRR activities by participating in the training programme and implementing the herd management techniques. CBRR also began to establish environmentally friendly income-generating programmes that started giving families better livelihood opportunities, especially after establishing the Tal Al-Rumman Women's cooperative society in 2016. It will continue to help more families as the project grows.

Opportunities and challenges of relying on the community–science knowledge base

The grazing management approach implemented by the CBRR programme assists in improving the biodiversity and biomass productivity of the RBG site. From 2008–2011, the biomass increased by 30 percent and 10 percent per year in subsequent years.

After implementing the managed grazing at the RBG site, a healthier, more diverse range of plants began to appear. When left unmanaged, open grasslands and woodlands are generally dominated by non-palatable annual grasses and herbs. Managed livestock grazing controls the growth of unpalatable grasses and herbs so that other desirable plants (wildflowers and native grasses) can regenerate and coexist with them. Many plants, including several endangered species, require grazing in order to maintain viable populations. The effects of the CBRR programme were noted as some plant species that disappeared from the region years ago have now spontaneously re-appeared. Additionally, the growth of trees within the RBG site was enhanced by limiting wood cutting, mulching the soil surface and enriching the soil properties. RBG plant surveys recorded the increase of species from 436 in the year 2008 to 602 in the year 2021. 22 plant species out of the 600 plant species are identified as endangered and critically endangered in the RBG site.

Notably, there have been constraints to overcome. Pastoralists were unprepared to assume the new responsibilities and not too many were willing to do so. Moreover, the social and economic situation of the area was challenging, given the low economic status of families in the area and a lack of technical and operational capacities over questions like grazing management or animal health. This situation reduced the pastoralists' resilience and adaptation capacity, also weakening their influence in land-use decision-making and grazing management control.

The role of grazing management in and restoring the flora of the Botanic Garden

In-depth analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that well-managed livestock grazing increases the diversity of habitats available to wildlife species. Many species,

including several endangered species, benefit from the vegetation management performed by livestock. Proper utilization of livestock grazing promotes healthier, diverse wildlife populations in rangeland.

An economic study performed among the five original herders in the first stages of CBBR implementation showed how support from RBG both indirectly from pasture (a mean value of USD 513 for each herder) and directly from barley supplements (a mean value of USD 433 for herder) improved their revenue between 6 and 159 percent (Al-Khalidi *et al.,* 2013). Additionally, benefits from targeted training and experience sharing are also available to the community. Such simple herd-management techniques contribute to optimizing the grazing management operations, as well improving overall land productivity. Applying the local knowledge to improve the science base monitoring and research has resulted in the CBRR rehabilitating 170 hectares of the total RBG site in a sustainable way compatible with traditional herding under a sustainable grazing management plan, with community participation. Since the implementation of the CBRR, the livestock owners who once grazed the site down to bare earth are policing themselves and others to protect the benefits they are reaping from the CBRR project and the rapidly reviving ecosystem.

Moreover, the CBRR also helped to improve the socioeconomic status of the herders in the target area through a governance approach, which led to a more sustainable ecological restoration of the site and also empowered the local community to represent themselves as a CBO. They are now more resilient and better adapted to climate change. This knowledge and expertise has been shared and transferred to other associations, non-governmental organizations and government organizations on a national and regional scale.

For more information

http://royalbotanicgarden.org/page/community-based-rangeland-rehabilitation-cbrr
http://royalbotanicgarden.org/page/publications

C: Theme 3: Silvopastoralism contributes to climate change resilience and adaptation and improves governance

The management of silvopastoral systems, the shaping of their ecosystems' properties, and their adaptive capacity and resilience make them an important part of sustainable land use. The previous themes highlighted the importance of silvopastoral management in improving the key ecosystem features and-enhancing both production (as seen in theme 1) and ecosystem health (theme 2), plus offering a great variety of solutions to deal with variable conditions caused by climate change and unsustainable land use. Silvopastoralist communities are key actors in helping bring about these benefits and thus improving their own livelihoods' adaptation mechanisms, and silvopastoralism demonstrates the potential to achieve climate change mitigation and adaptation synergies. For instance, optimizing carbon storage using adjusted grazing pressure, integrating forestry and livestock management or reducing emissions by diversified livestock diets also contributes to helping the system adapt to climate change (e.g. providing shade and shelter and expanded feed periods) and increases its resilience (by improving animal welfare or diversifying production). This path from multifunctionality to resilience provides a clear example for implementing agroecological strategies and adaptively managing other food production systems.

By contrast, abuse of the system, unbalanced extraction of resources, broken links and pressure over key features, simplification, or abandonment will disturb the whole management system, reducing its outcomes and worsening overall conditions. External factors, such as extreme effects of climate change, fragmentation, land grabbing, overpopulation, inappropriate policies, and so on, could increase pressures on the system, generating additional threats that can reduce its performance, hence excluding people and turning the direction of the loop towards degradation and malfunctioning.

Accordingly, silvopastoral management requires the collaboration of different agents in charge of different activities on the same land base, cooperating in a flexible way that allows balanced decision-making, which should keep the system at its best no matter how different the interests. Importantly, silvopastoral management systems also demand good land governance frameworks and institutions to enhance stakeholder dialogue and engagement in concrete actions. However, enhancement of the good governance and institutional frameworks is a

challenge, especially when collective rights for common lands or complex mosaics are threatened by more private approaches.

Silvopastoral lands also host important achievements in terms of land rights and improved flexible tenure systems for multiple resources and different land users. Innovative nature-based solutions could contribute to supporting multidisciplinary stakeholder platforms that advocate for applicable and scalable well- managed silvopastoral practices. The last case studies presented in this chapter show how the pioneers in legal developments promoting the use of silvopastoral lands under participatory, multistakeholder and sustainability approaches encapsulate this effort not only to preserve dryland silvopastoral landscapes but also to profit from all its potential to improve the resilience and adaptation capacity of forest ecosystems and the communities managing them.

There are promising examples and initiatives implemented by FAO and others that show how SPS can be adapted to cope with global changes in terms of land use, climate, or technology and contribute to turning the tide on land degradation, especially at the country level. This theme spotlights cases from the silvopastoral systems in The Islamic Republic of Iran, Senegal, Lebanon, Brazil, Morocco and West African countries (the United Republic of Tanzania, Ethiopia and Kenya), and their potential contribution to resilient governance systems with special consideration of different criteria and potential outcomes from combining trees and forests with grazing livestock as shown in Table 4.

On the policy side, some governments are currently developing silvopastoral and agrosilvopastoral approaches, combining the interventions of institutional partners with civil society and pastoral organizations to deliver a shared vision and adequate policy development frameworks. Besides the two case studies, presented, other countries as Burkina Faso have also started this path to recognize and promote silvopastoralism and agrosilvopastoralism.

CASE STUDY 12: CHARACTERIZING GRAZING LIVESTOCK SYSTEMS FOR TAILORED ADAPTATION SUPPORT IN FATICK, SENEGAL

Fatick region located in the western centre of Senegal and characterized by its semiarid steppes is characterized by natural pastures, with low-growing grass and herbaceous perennials, thorny shrubs, acacia and baobab trees. These features make the region suitable for livestock activities, which represent the second most important source of income after crop production. Even though livestock activities are practised by almost 70 percent of the population (ANSD, 2015), Fatick region remains among the poorest in the country with a poverty index of 49.2 percent, compared to 37.8 percent nationally (ANSD, 2021a). Traditional crop-tree-livestock systems are considered the main provider of food, nutrition, income and ecosystemic services. Communities in Fatick practise transhumance due to the extension of agricultural areas and the shrinking of grazing land (Robinson *et al.,* 2011). The livestock sector in particular occupies 28 percent of the population and contributes 23.7 percent of agricultural GDP (ANSD, 2015, 2021b). However,

climate change and degradation of the landscape are increasingly threatening the livelihoods of the already impoverished rural population.

Livestock farming in the region is mostly characterized by traditional practices dominated by pastoral transhumance and sedentary agropastoral production in rural areas. Average livestock composition in the region includes a 59 percent of small ruminants and 20 percent of cattle (ANSD, 2021b). Women, in particular, are responsible for raising sheep and goats, in addition to the milk processing and packaging. Despite these constraints, livestock farming is developing in the Fatick region, particularly with the specialization and intensification of dairy production. This sector represents a major opportunity for the sustainable development of the region through increasing productivity, income and food security and building resilient agroecosystems in the face of climate change.

Livestock systems in Fatick as a pathway toward inclusive, resilient livelihoods

Understanding the different livestock systems in practice in the Fatick region is of central importance in designing and implementing sustainable solutions that reflect the local realities, especially in the face of increasingly uncertain environmental conditions. Yet it remains important to examine: (a) how these systems are managed and contribute to sustainable development; (b) what risk management strategies are adopted by producers; and (c) how to make the most of the opportunities that the sector offers while including perspectives of producers, especially women. With these issues in mind, a study was conducted in Fatick in 2019 under the FAO project "Strengthening Agricultural Adaptation" (SAGA) in collaboration with McGill University, the Senegalese Institute of Agricultural Research and *Pastoralisme et zones sèches en Afrique de l'Ouest*. The main objective was to examine the livestock production in Fatick, grazing systems in particular, in terms of their strengths, weaknesses, opportunities and threats (SWOT) to promote these systems in adaptation planning and national development strategies (For additional details, see Habanabakize *et al*., 2022).

The study was guided by a participatory action-research approach, including the main stakeholders (producers, researchers and local institutions) from the very beginning to identify indicators that would reflect local realities to characterize livestock systems in Fatick. Such consultation helped the team to determine the topology of livestock systems by interviewing 100 heads of households who are engaged in livestock production across the region to analyse for example, where farmers stand on the use of trees, agroforestry practices, or grazing. Figure 13 summarizes the results of the sector's SWOT analysis in the context of climate resilience and food security against the four sustainability pillars – good governance, economic, environmental and social – of FAO's Sustainability Assessment of Food and Agriculture systems (SAFA). Based on this, joint recommendations were made to improve the silvopastoral systems in Fatick region.

FIGURE 13

SWOT analysis of two grazing-based systems predominant in Fatick: Cluster 1, labeled as agropastoral; cluster 2, labeled as pastoral. Cluster 3, labeled as semiextensive is not included*

Cluster 1 – Agropastoral

Strengths

- Crop-livestock integration,
- Diversified production systems (subsistence crops, vegetables, cattle, small ruminants, poultry, etc.)
- Use animal byproducts for soil fertility.
- Use of crop residues to feed animals; Land conservation practices.

Weaknesses

Low and inconsistent production. Lack of access to markets. Extension and climate information. High diseases rates. Few to no land titles. Low participation of women.

Opportunities

- Policy promoting value chains development (e.g. theNational Program for Livestock Development (PNDE))
- National Adaptation Plan for the Livestock sector.
- National multi-stakeholders' engagement for increased advocacy and knowledge sharing.
- High local demand for raw milk, meat and processed products.
- Women entrepreneurship.

Threats

- Limited access to funds and credit
- Rainfall variability and droughts
- Soil salinization
- Fragile vegetation cover
- Conflicts between livestock herdsmen and crop farmers
- Lack of financing for capacity development of stakeholders' organizations
- Food insecurity.

Cluster 2 – Pastoral

Strengths

- Transhumance as an adaptation to feed scarcity and changing weathers.
- Large and diversified herds of local livestock breeds adapted to local conditions
- High selling price for milk
- Strong women participation
- Livestock as a social prestige.

Weaknesses

- Overgrazing; Low and inconsistent production
- Low profitability.
- Lack of access to markets, extension and climate information and low education levels.
- Little to no crop-livestock integration.

Opportunities

- Policy promoting value chains development (e.g. PNDE)
- National Adaptation Plan for the Livestock sector.
- Stronger multi-stakeholders' engagement for increased advocacy.
- Consultation and knowledge sharing.
- High local demand for raw milk, meat and processed products.

Threats

- Low land access that leads to transhumance and reliance on communal grazing
- Rainfall variability and droughts
- Deforestation; Shortage of fodder during dry season
- Conflicts between livestock herdsmen and crop farmers
- Limited access to funds and credit
- Lack of financing for capacity development of stakeholders' organizations.

*Attributes like crop-livestock mixed systems, seasonal and low milk production and female participation are found in cluster 1 while cluster 2 is characterized by farms with bigger herd sizes, highly mobile farmers and the lowest quantities of sold milk. Cluster 3 is mainly made up of farms with stable quality and consistent milk productions, generally located in urban or peri-urban areas close to roads, markets and veterinary services infrastructures. Clusters 1 and 2 represent 72 percent of the sample, making grazing livestock systems predominant in the studied area. Except for a few producers in cluster 3, all the others have resorted to transhumance as an adaptation means to prolonged droughts, which are frequent in the region.

Trees, crops and livestock: promising synergies for smallholders

Livestock producers have developed different practices linking livestock, trees and crops. Those practices, ranging from tree plantations, integration of legumes in crop cultivation, forestland, avoidance of tree pruning and limiting overgrazing, were compared to examine the role of farmers in ecosystem conservation. When integrating crops and trees, farmers are expected to improve soil quality and reduce land degradation. More than half of farmers in cluster 1 were implementing these practices. Statistical analysis showed no significant differences regarding the impact of each cluster on biodiversity. However, overgrazing was identified amongst the main threats for farmers in cluster 2. Developing crop-tree-livestock integration could be an opportunity to promote agroforestry systems. Nevertheless, land property documents limited farmers' access to land and are key obstacles to tree planting. Farmers are reluctant to invest in long-term adaptation options on land if they do not own it. In fact, 95 percent of farmers in clusters 1 and 2 did not have proper land title documents.

Collectively, all clusters faced the same challenges around the lack of access to markets, extension and information on weather/climate, feed scarcity, water access and the majority of the ageing population involved in livestock production activities. A range of policy solutions is needed to address the heterogeneity present within the sector and target groups with their specific needs. The analysis provided insight into specific recommendations towards improving the dominant grazing-based systems (clusters 1 and 2), which were also found to be the most vulnerable. Moreover, increasing support for these producers to make the shift toward more resilient production could significantly improve livelihoods and ecosystems.

The need for research to inform policy decisions and tailored interventions toward inclusive, resilient and sustainable livestock systems at the farm and value chain levels.

Analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that the information gathered by the project strengthened the alignment of scientific evidence with farmers' perspectives, especially smallholders, and generated insights for adaptation governance and sectoral development strategies using an inclusive approach. Further research is still needed to explore quantitative indicators to evaluate the environmental and socioeconomic implications of grazing systems and how the results can be mainstreamed in national and local interventions. The following recommendations were drawn from the study and are key to improving the silvopastoral systems' reliance and adaptation, and could thus be useful to inform national climate policy processes, more specifically the National Adaptation Plan and Nationally Determined Contribution:

- Diversification of products from trees, crops and livestock could reinforce the resilience of farming systems through processes of nutrient recycling, biodiversity management and integrated pests and disease control, as well

as increasing sources of food and income. This applies particularly to agropastoral systems in cluster 1. Increasing support for smallholder farmers to make the shift toward the integration of crops and trees into their livestock systems could significantly improve livelihoods and ecosystems.

- Re-seedling suitable fodder species as well as introducing trees and multipurpose woody species that withstand cropping and lopping for fodder could also improve the vegetation cover of rangelands and the resilience of the grazing system to climate variability and provide animal feed.
- Community-based natural resource management could be an entry point to capacity building in grazing management and good governance (rights, organizational management). There is a pressing need for pastoral systems in cluster 2 to ensure good management and sustainable use of natural resources in the fragile Fatick ecosystems.
- Access to proper tenure rights would also attenuate and manage the growing tensions and conflicts between farmers over land and pastures. This is crucial in securing and balancing crop, pastoral and forestry areas within laws and regulations governing land tenure. Low perceived security ensuing from a lack of ownership over the land strongly affects the willingness and ability of producers to make long-term investments toward the sustainability of the operation.
- Gender action-learning strategies could engage both women and men in the conversation by showing that empowering women means empowering the household and community. The gender lens is important to identify and address women's needs to improve their livelihoods and those of their households. However, the study highlighted that more efforts are needed to scale up initiatives in which women are more likely to be involved in livestock production, such as selling fresh milk, small-scale processing and marketing of dairy products. In addition, access to property rights can also positively affect women's control over adaptation.
- Better access to reliable weather information and forecasting would help both herders and farmers, as well as local institutions, to improve their decision-making in planning their production activities.

For more information:
FAO project "Strengthening Agricultural Adaptation" (SAGA)
Habanabakize *et al*., 2022).

CASE STUDY 13: COMMUNITY MOVEMENT FOR ECOSYSTEM AND LIVELIHOODS RESILIENCE IN THE ISLAMIC REPUBLIC OF IRAN

Oshtorankuh Protected Area is a mountainous semiarid region where remnants of the originally widespread oak-dominated woodland and the park-like pistachio and almond steppe lands can still be found. Although it is currently deforested and degraded because of overgrazing, the protected area has a high rate of biodiversity

Cluster 1 – Agropastoral

Strengths
Crop-livestock integration; diversified production systems (subsistence crops, vegetables, cattle, small ruminants, poultry, etc.); use of animal byproducts for soil fertility; use of crop residues to feed animals; land conservation practices.

Weaknesses
Low and inconsistent production; lack of access to markets, extension and climate information; high diseases rates; little to no land titles; low participation of women.

Opportunities
Policy promoting value chains development (e.g. The National Programme for Livestock Development; National Adaptation Plan for the Livestock sector; national multistakeholder engagement for increased advocacy and knowledge sharing; high local demand for raw milk, meat and processed products; women's entrepreneurship.

Threats
Limited access to funds and credit; rainfall variability and droughts; soil salinization and desertification; fragile vegetation cover; conflicts between livestock herdsmen and crop farmers; lack of financing for capacity development of stakeholders' organizations; food insecurity.

Cluster 2 – Pastoral

Strengths
Transhumance as an adaptation to feed scarcity and changing weathers; large and diversified herds of local livestock breeds adapted to local conditions; high selling price for milk; strong female participation; livestock as a social prestige.

Weaknesses
Overgrazing; low and inconsistent production, low profitability; lack of access to markets, extension and climate information and low education levels; little to no crop-livestock integration; low land access that leads to transhumance and reliance on communal grazing.

Opportunities
Policy promoting value chains development (e.g. PNDE); National Adaptation Plan for the Livestock sector, stronger multistakeholder engagement for increased advocacy, consultation and knowledge sharing; high local demand for raw milk, meat and processed products.

Threats
Rainfall variability and droughts; deforestation; shortage of fodder during dry season; conflicts between livestock herdsmen and crop farmers; limited access to funds and credit; lack of financing for the capacity development of stakeholder organizations.

and is under nature protection by the Department of Environment of the Lorestan province (Bayat Hamidreza, Henrik Majnounian, 1988, Oshtorankouh Protected Area, Department of the Environment, the Islamic Republic of Iran).

According to available information, about 70 293 ha (67.3 percent of the protected area) is covered by 32 vegetation types of rangeland species, and 17 398 ha (16.6 percent) is covered by two forest stand types, including *Quercus-Juniperus* and *Quercus-Amygdalus*, in which a variety of rangeland species form the ground cover. According to the 2012 Management plan of Oshtorankuh Protected Area, more than 600 herbal species and 274 animal species have been identified in the region.

Oshtorankuh protected area is facing real challenges

These pastures with scattered trees form a comprehensive and multifunctional silvopastoral system with integrated production: pastures supply livestock fodder and medicinal plants while trees (after traditional pruning) supply part of the fodder as well as its foliage for fuel wood and making livestock shelter. Besides, oak seeds are used to make traditional bread. Unfortunately, the production of coal from oak trees, which has become very popular in recent decades, has become one of the main sources of income for the local community, degrading the local ecosystem. This project has focused one of its goals on training the local community on the ES of a tree compared to a sack of charcoal to curtail this practice.

The oak forests are mostly degraded and only scattered trees form the upper story, while the lower story is highly degraded by intensive grazing or rainfed cultivation. However, pruning could be performed using the traditional methods so as not to harm the trees. However, most scientists believe that considering the stocking rates and mismanagement of rangelands, the whole ecosystem is weakening and pruning should be stopped. Additionally, other sloping and rocky areas, covered by bushes and shrubs, are not considered rangelands, but only wildlife pastures/habitats. The considerable vegetation cover in this protected area is limited to the core zone around Gahar Lake at the mountaintop, which is designated as a grazing forbidden zone. Goats have always been a big challenge for these oak forests. Grazing in the core zone is strictly forbidden but illegal grazing occurs in core zones all over the country. This lack of understanding between herders and government managers is also harming the core areas. Besides, wildfires, both intentional and natural, are and have always been one of the major problems of the Zagros oak forests and many creatures, including humans, have lost their lives in attempts to extinguish them. Accordingly, another side effect of banning livestock grazing is that the probability of fire increases, especially in tourist areas such as the shores of Lake Gohar. However, due to the lack of a codified action plan to control livestock grazing and other challenges mentioned, livestock is prohibited from entering these areas.

Rangelands are also degraded in many sites. Among the causes is the destruction of customary management and governance systems and the disintegration of

nomadic territories of summering and wintering grounds into a piece of land. Nomad sedentarization is driven by the loss of the sense of belonging among nomads due to nationalization of natural resources while the loss of customary ownership and land rights is also a key driver.

Traditional knowledge have been neglected in the management of these areas, particularly in the hierarchy and non-participatory aspects. This means that a sense of false competition between the government and the herders arises around the use of resources, especially when these lands are rented to external stakeholders. For the local talent, this increases the stocking rate to over the grazing capacity of the lands, ultimately degrading the entire ecosystem.

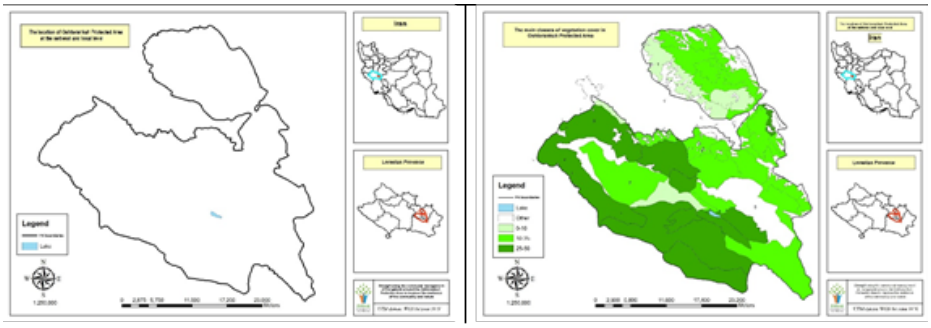
Strengthen Iranian pastoralist CSOs to improve natural resource governance

The Islamic Republic of Iran has one of the largest nomadic populations in the world, an estimated 1.5 million in a country of about 80 million. Tribal communities have used natural resources as their only source of livelihood for thousands of years. However, the country's tribal pastures, which mostly refer to a mixed grassland-woodland ecosystem, were nationalized during the 1960s, after which the customary management systems broke down. Traditional management units like tribal territories and in particular rangelands with scattered trees, have been divided into official management units. This is what inspired the Center for Conservation and Development of Sustainable Ecosystems to partner with the International Union for the Conservation of Nature (IUCN) and begin a European Union (EU) funded project in 2014 entitled "Strengthening the communal management of Rangeland around the Oshtorankuh Protected Area to improve the resilience of the community and nature". It was to conserve the protected area in facing climate change and droughts.

The activities implemented in demonstration sites in Oshtorankuh Protected area Lorestan Province (Figure 14) took into consideration the needs of women and pastoralists to secure through strengthening their customary–tribal management system.

FIGURE 14

Demonstration sites in Oshtorankuh Protected area in Lorestan Province, Iran.



Source: ZIPAK NGO and IUCN ROWA. 2021 Strengthening the communal management of Range-land around the Oshtorankuh Protected Area to im-prove the resilience of the community and nature.

The project has used a compilation of different gender-sensitive participatory-based methodologies as a framework for the different actions taken. The basic methodology used in this project was the Restoration Opportunities Assessment Methodology, produced by IUCN and the World Resources Institute. The team applied a participatory rangeland action planning to strengthen community ownership of restoration and other environmental activities and build planning and monitoring capacity and sustainability, as well as guide the development of a shared vision on conserving the protected areas by securing the customary rights and local governance system. Accordingly, pastoralists were encouraged to use their local and Indigenous knowledge and combine it with scientific advice to mobilize their potential local solutions. Civil society groups were trained to develop their shared vision, identify challenges and agree on actions to conserve the protected area. Moreover, the extensive internal monitoring and evaluation system designed benchmark indicators used to measure the achievement of activities' outputs and change and impact indicators to measure the achievement of results and outcomes.

Grazing time and period are key in restoring the Oshtorankuh Protected area.

Analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that the project managed to restore 3720 ha (almost equally split between the three pilots) through partnership, cooperation and social solidarity in pilot areas to be scaled up in the whole protected area and later to similar situations. Rural communities who are relying on livestock as the main livelihood managed through the project's interventions to use forest and rangeland by-products (including medicinal plants, fuel wood, fodder and shelter and tree seeds for food) to generate additional income. For example, women in Oshtorankuh have improved their skills in processing livestock products, handicrafts and the collection of forest by-products.

Thanks to the active participation of the tribes, the communities managed to solve the issue of early grazing, which is one of the main causes of rangeland degradation. Moreover, observing the climatic conditions and precipitation season and the phenology of plants by grazing livestock in the region indicates that the whole area is rather summer grazing ground. The communities' plans identified that the most appropriate time for livestock grazing in the area is during the three summer months, with the exception of the lower areas that can occasionally be used for spring grazing, starting as early as May. This would cause less damage to the vegetation and establish proper conditions for the regeneration of the rangeland ecosystem. Interestingly, the project also strengthened pastoralist CSOs towards improving natural resource governance and climate change resilience through various training and behavioural awareness campaigns. As a result, local communities recognized and appreciated different stakeholders involved in managing the protected areas and mainly the governmental entities.

Indigenous communities enforced their knowledge through a consortium

The project approach combines government woody rangeland restoration policies and strategies with visionary and management capacities of local communities, in joint dialogue and responsibility-sharing initiated measures for scaling up lessons learned. As a result, the revival and support of the customary management system known as *hima* and support for Indigenous Peoples and community-conserved areas and territories (ICCA) were appreciated by the different stakeholders as an attempt to bridge the policy–implementation gap in the Oshtorankuh area and have created a good opportunity for scaling up to the entire county via their integration into a national rangeland policy.

Indigenous Peoples managed to express their needs and establish their voluntary ICCA consortium in 2010 to promote equity in conservation. The consortium supported the communities in the demonstration sites in establishing and enforcing rules and regulations for rangeland resources, promoting natural revegetation and recovery of soil and water cycles. Among the measures taken by the local community are the collection and cultivation of seeds of the tree and herbaceous species and their protection, seasonal and periodic ex-closure of pastures, cessation of cultivation under floors, especially in sloping lands, reduction of livestock based on the grazing capacity, small-scale watershed management operations and sustainable use of medicinal plants. The Government is also committed to providing the necessary facilities and inputs for this purpose.

Under this project, the tribal territories have been discovered and the borders have been enclosed through participatory mapping and land planning. To revive the governance systems, the social structure of the tribal communities and the customary rangeland management systems have been specified with the help of community elders. The Lorestan Nomadic Union including the Zalaqi, Mamivand and Hajivand tribes, is one of the established community-based organizations in the region. All the compiled information was documented for every tribal territory to be discussed and included in the national rangeland policies.

Through consortium networking and advocacy at national and subnational levels, custodian Indigenous Peoples and local communities become better connected with other communities, better recognized, defended, respected and appropriately supported locally, regionally, nationally and internationally. The consortium supported the meetings with parliamentarian representatives to voice their needs and demonstrations. This helped strengthen communities' ecological knowledge and embed it in cultural and spiritual relationships.

CASE STUDY 14: TRADITIONAL AGROSILVOPASTORAL SYSTEM IN MERIDIONAL ESPINHAÇO RANGE (MINAS GERAIS STATE/BRAZIL)

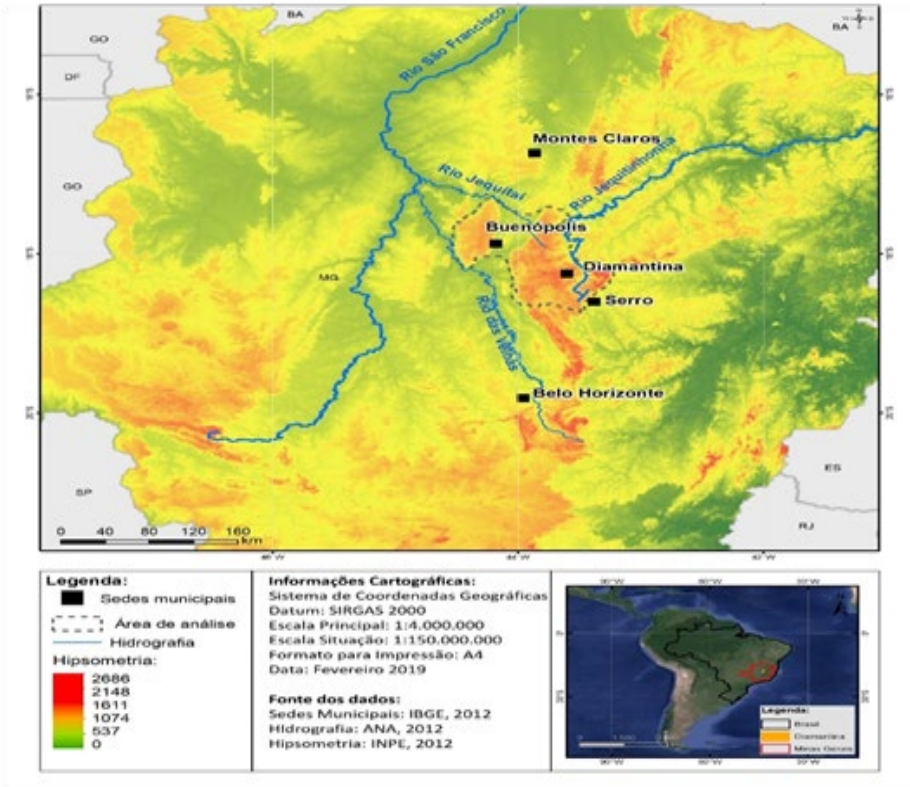
The Espinhaço Range constitutes a wide savannah area in close contact with steppic savannahs, both of which are characterized as dryland. Those lands had been occupied for a long time by "traditional peoples" (the Brazilian term for Indigenous and African descendants and peasants on common lands).

The niche of Sempre-Vivas flower gatherers' communities and practices in the Brazilian Cerrado

The "*Apanhadoras de flores sempre-vivas*" (Sempre-Vivas flower gatherers) traditional communities live in the meridional part of the Espinhaço Range in the central region of Brazil (Figure 15). The communities practise a traditional agrosilvopastoral system characterized, among other features, by the use of common lands for mobile livestock and gathering medicinal plants and native flowers. As shown in figure 16, the families use the lowlands (600 m altitude) for cultivation and animal breeding during the rainy season and the highlands (1 400 m altitude and characterized by their rupestrian grasslands with trees in savannah vegetation) to feed the cattle in the dry season of the year. During the dry season, the lowland cultivated pastures dry up drastically and stop producing food for the animals. On the other hand, the altitude condition of highlands keeps them moist and guarantees grazing opportunities for the animals on native vegetation in the dry season, while trees are very important to keep humidity in the soils and the conservancy of water resources.

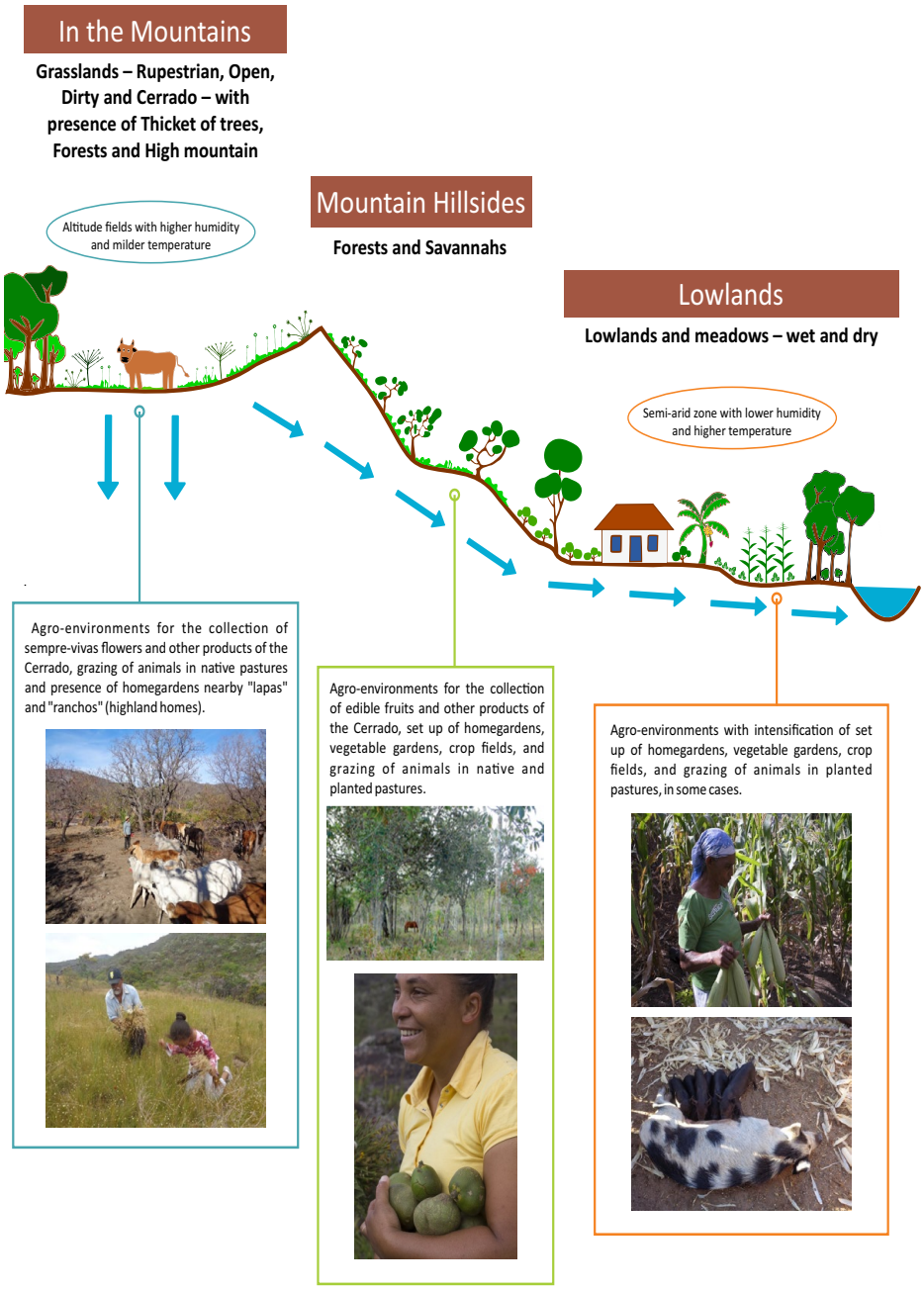
Accordingly, the seasonal movements express the transhumance of families and local groups with their cattle herds, overcoming agroecosystem limits and exploiting many of the region's different potentials. During the traditional transhumance, the families live in caves and simple houses built with local materials in the mountains. In general, families travel either together or even separately to "gather" or harvest the flowers and manage the cattle in the mountains and native pasturelands. They can stay for weeks or months, depending on the local conditions. When families from different communities meet in the native fields, it is an occasion for gatherings, parties and bonding. In this manner, the system deals with landscape verticality and horizontality that confer elasticity/flexibility to local agrifood and economic familiar strategies through cultivation, native plant collection and animal breeding.

FIGURE15
The "Sempre-Vivas Flower Gatherers" communities located in the Brazilian Cerrado



Source: Monteiro, F. T. 2021. Nas Fronteiro das Minas com os Gerais: as terras de uso comum e o uso coletivo de terras. 1. ed. São Paulo: Editora Annablume. Vol 1 e vol 2. 740p.

FIGURE16
System synthesis in Sempre-Vivas flower gatherers


In the Mountains
Grasslands – Rupestrian, Open, Dirty and Cerrado – with presence of Thicket of trees, Forests and High mountain
Altitude fields with higher humidity and milder temperature
Mountain Hillsides
Forests and Savannahs
Lowlands
Lowlands and meadows – wet and dry
Semi-arid zone with lower humidity and higher temperature
Agro-environments for the collection of sempre-vivas flowers and other products of the Cerrado, grazing of animals in native pastures and presence of homegardens nearby "lapas" and "ranchos" (highland homes).
Agro-environments for the collection of edible fruits and other products of the Cerrado, set up of homegardens, vegetable gardens, crop fields, and grazing of animals in native and planted pastures.
Agro-environments with intensification of set up of homegardens, vegetable gardens, crop fields, and grazing of animals in planted pastures, in some cases.

Source: Elaborated by case study authors

Research is needed to unpack traditional agrosilvopastoral techniques used by Sempre-Vivas flower gatherers

In 2017, in a bid to understand the logic underlying the traditional techniques used by the flower gatherers and the system's agrarian metabolism, and in partnership with the regional commission of communities, the Commission to Defend the Rights of Sempre-Viva Flowers Gatherers' Communities, and the Research Group on Territories, Socio-biodiversity and Agricultures, São Paulo University and Federal University of Jequitinhonha and Mucuri Valleys in the Minas Gerais State began their research on the "Brazilian Traditional Agricultural Systems".

The research set out to quantify and qualify the agroecosystem services generated with a view to contributing to the construction of public policies aimed at traditional agricultural practices. It targeted the traditional agrosilvopastoral system managed by six communities made up of approximately 1 500 individuals in a total area of almost 100 000 hectares in those savannahs, known as "Cerrado" (Monteiro et al., 2019). Those communities form part of the Globally Important Heritage Agricultural System designated in 2020, the first in Brazil (FAO, 2020).

Sempre-Vivas flower gatherers' traditional agrosilvopastoral system can be considered as a way of life and production model for rural communities in the Cerrado ecosystems

The Sempre-Vivas flower gatherers' agrosilvopastoral system combines different altitudes with different moisture content in a semiarid climate zone, on predominantly acidic, sandy and dystrophic soils. It is based on the application of high-biodiversity-based tools for food and agriculture, which are already adapted to the local different edaphoclimatic characteristics. Among their main assets, there are 94 cultivated species, 16 species of domestic animals, 350 species of native flowers and 135 other non-timber forest products. The whole system depends on traditional associated knowledge for the use and sustainable management of natural resources, generating a better-conserved forest area in the region.

The use of high biodiversity adapted to the different edaphoclimatic characteristics generates different agroenvironments and landscapes. In this sense, transhumance works as a mechanism for overcoming agroenvironmental limits and exploiting a great deal of the region's different potential assets. In addition, the management is centred on biomass cycling, which guarantees and improves the flow of matter and energy for agrifood production, also raising the pH and natural fertility levels of the soils. At the same time, this management ensures the conservation of natural resources through the soil-plant-water relationship.

Those management practices boost natural processes and cycles (energy, nutrients, organic matter, biotic interactions), preserve renewable natural resources (soil, water, biodiversity), improve the economy and boost independence in relation to non-renewable natural resources (fossil fuels, among others) and industrial inputs, reducing consumption of external inputs and avoiding and rejecting harmful ingredients (pesticides, genetically modified crops, anabolic steroids). Thanks to transhumance and their culture and traditions, these local

communities transport species from one place to another and preserve them as a family legacy, favouring adapted local genetic resources. The profound knowledge of the environment allows them to collect flowers and other wild species, preserving regeneration for the coming period of the year while spreading the seeds in other optimum places during their seasonal transhumance movements between higher pastures and lower valleys

Flowers and buds are locally managed in their own habitat using conservation practices, including: i) respecting the ripening point for collection in which part of the seeds have already been expelled by the plant, ensuring new individuals; ii) the fact that during collection the families leave 30 percent of individuals without collecting and these residual individuals are also responsible for the conservancy of the species populations; and iii) the return of seeds that fall into the flower storage places to the native fields, a process known as "enrichment". These practices, among many others, aim to maintain and expand the populations of species managed and marketed by families. In all cases, the collection of forest products – both timber and non-timber, occurs according to the lunar calendar and vegetative cycle in order to conserve community forest resources.

The presence of "*curraleiro*" cattle breeds stands out in these communities, even though other breeds have already been incorporated into the production system. *Curraleiro* refers to the first breed to arrive in Brazil with the colonizers, having been recognized in 2012 as a Brazilian breed by the Ministry of Agriculture, Livestock and Supply. Cattle stocking rates are maintained in native community pastures, establishing a relationship between cattle raising and the territorial management of each community. Similarly, water and forest conservation is considered in their land management practices, including reducing the impacts of forest fires by decreasing biomass through grazing.

The community lands generally have more than half of their surface occupied by forests, rocky outcrops, escarpments and high-slope soils, whose conservation, on the other hand, is necessary for the maintenance of water resources. Accordingly, cattle walk long distances in search of more palatable grasses amid native rangelands. Families can also walk long distances to reach "spots" of native flowers, while spots of suitable soil for cultivation can be a few kilometres from houses between slopes and valleys. All these movements are carried out by respecting the rhythms of natural cycles and optimizing their energy and nutrient flows. Therefore, the management of the landscape is closely related to the community's way of life.

Understanding the food culture is important to enhancing socioecological resilience in agrosilvopastoral areas in the Cerrado

Analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that the agrosilvopastoral system combines different altitudes with different moisture content in a semiarid climate zone, on predominantly acidic, sandy and dystrophic soils. It is based on the use of high biodiversity-based tools for food and agriculture, which are already adapted to

the local different edaphoclimatic characteristics. The whole system depends on traditional knowledge for use and sustainable management of natural resources, generating better-conserved forest areas in the region, with women playing a key role. Their seasonal movements express the transhumance of families and local groups with their cattle herds, overcoming agroecosystem limits and exploiting many of the region's different potentials.

There is also a direct relationship between agricultural biodiversity and food culture. As with other aspects of their heritage, women play a leading role in preserving this food culture and the intergenerational transmission of knowledge. All the families in these communities possess home gardens, crop fields and livestock, and gather a range of forest products. Women do most of the work in home gardens and raising small animals and a fair amount of work in collection, taking care as well of animal health and crop fields. In this way, the women play a key role in the agrobiodiversity conservation directly connected with food culture and in the family's food and nutritional security. They also hold training activities and surveys for decision-making in the communities and in the regional commission.

Communities also play a key role in the management of the water cycle through adaptive techniques. Similarly, genetic resources are collectively managed through the selection, storage and distribution of locally adapted seeds and livestock breeds for agriculture and food, combining different architectures of plants in polycultures with the maintenance of mulch over the soils while observing the food culture and values.

The research also highlighted that the multifunctional management systems analysed can lead to high food security, socioecological resilience, increased income generation, better managed landscapes and social reproduction of cultural diversity. The agroecosystem products and services generated serve the local communities and global society in terms of conservation of biodiversity, water resources and climate regulation in the context of climate change. In addition, they bring important knowledge to bear about sustainability in time and space through dynamic conservation and solutions based on nature.

It is important to monitor the evolution of these benchmark agroecosystems, their resistance to local adversities and their resilience to climate change in dryland, in which some of the key indicators are: biodiversity, biomass and carbon, with special attention to the role, rights and economic inclusion of women. However, there are conflicts between the communities and natural parks created on their ancestral common lands. Dialogue between the regional commission of traditional communities and the government is currently aiming to guarantee their rights as provided for in federal and state law and international treaties.

For more information

www.fao.org/giahs/giahsaroundtheworld/designated-sites/latin-america-and-the-caribbean/semprevivas-minasgerais/annexes/en/

CASE STUDY 15: PARTICIPATORY RANGELAND MANAGEMENT – AN ENABLING PROCESS FOR IMPROVING SILVOPASTORAL MANAGEMENT AND GOVERNANCE

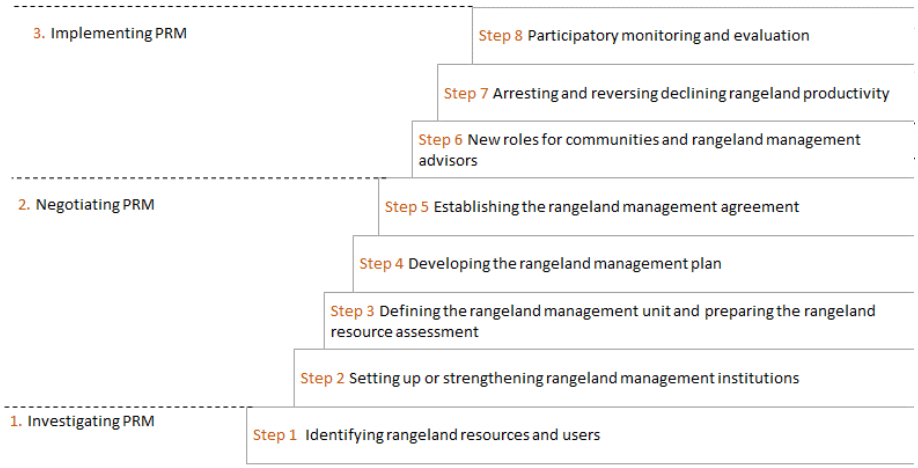
Pastoralists are facing new challenges that require an organized and collective response, besides working with other stakeholders. Rangelands including silvopastoral lands in Africa and Asia are usually managed collectively, with complex arrangements defining users and uses at multiple scales. This management is often undertaken in a context of tenure insecurity, providing little incentive for land users including pastoralists to invest in the land to improve productivity or restore it where degradation has taken place. This is especially true in the case of forest lands and lands with trees, although these lands and the trees on them provide important local, regional and planetary ES (Coppock *et al.,* 2017). Without tenure security and greater feelings of secure access or ownership, there are few incentives to make long-term investments, for instance, in tree planting and land management strategies. Additionally new challenges are facing pastoralists that they are ill-equipped to deal with, for example invasive species not seen before and that have spread at alarming rates. Responding to such challenges requires an organized and collective response, working with other stakeholders such as governments, private companies, or NGOs.

Participatory rangeland management can strengthen SPS

Participatory rangeland management (PRM) is a process that was developed to address such challenges. PRM builds on and incorporates the same principles of participatory forest management, as in planning and governance terms there are many similarities between the two land types. Furthermore, as trees and shrubs are often an integral part of rangelands and livestock often graze in forests there can be a natural convergence of management objectives and instruments. PRM seeks to improve tenure security for land and resources for pastoralists, improve management and governance including at multiple levels and with multiple users, improve land productivity and livestock health, and give pastoralists greater options for adapting to climate change and/or responding to drought and other crises.

Developing participatory rangeland management to address pastoral challenges

As in participatory forest management, PRM follows three stages: 1) investigation; 2) planning; and 3) implementation. The stages are divided into ten or so steps, working towards defining an appropriate unit for rangeland management (such as a traditional grazing area) with the community and other stakeholders, the documentation of rangeland resources and their status and the strengthening or setting-up of a governing community association or institution. Once these are in place, a rangeland management plan is developed based on an in-depth rangeland inventory and community action planning. Access to resources is improved through the drawing up of a legally binding rangeland


3. Implementing PRM
Step 8 Participatory monitoring and evaluation
Step 7 Arresting and reversing declining rangeland productivity
Step 6 New roles for communities and rangeland management advisors
2. Negotiating PRM
Step 5 Establishing the rangeland management agreement
Step 4 Developing the rangeland management plan
Step 3 Defining the rangeland management unit and preparing the rangeland resource assessment
Step 2 Setting up or strengthening rangeland management institutions
1. Investigating PRM
Step 1 Identifying rangeland resources and users

Source: **Flintan, F. & Cullis, A**. 2010. Introductory Guidelines to Participatory Rangeland Management in Pastoral Areas (Vol. 251).

Piloting inclusive governance to be scalable to a different level

PRM was originally piloted in several sites in Ethiopia and was then scaled up to more than a million hectares across pastoral areas in the country. A 2019 review of this implementation (Flintan *et al*., 2019) highlighted the positive gains of the process in strengthening inclusive governance institutions, with particular improvements in the increased participation of women, managing resources and improving the productivity of the land. PRM also contributed to stronger perceived land and resource security, willingness to invest in SLM, and opportunities for improving livelihoods. However, several areas for improvement were also highlighted. These included the need to work at multiple scales (landscape and local), the need for an enabling environment and or interventions targeting this and the importance of maintaining flexibility – PRM is not a linear process and requires adaptation to local contexts and changing conditions.

With these successes and areas for improvement in mind, PRM was then adapted to and piloted in Kenya and the United Republic of Tanzania. The European Union-funded Piloting of PRM Project, implemented by a group of technical and policy-oriented partners, ran from 2018 through to 2021. A recent evaluation of the project concluded similar results to the review of PRM in Ethiopia with more than 94 percent of community members interviewed stating that rangeland conditions had improved, which resulted in improved livestock condition and numbers. 90 percent described improved participation in rangelands governance and management and greater security of rights to land and resources with improved participation of women, 86 percent reported fewer conflicts and over 80 percent indicated that PRM has contributed to improved livelihoods, food security, increased incomes and an enhanced capacity to deal with drought (Waweru *et al*., 2021).

Applying PRM in silvopastoral settings

The principles and process of PRM are familiar, building on and adapting participatory forest management. However, some fundamental differences between forests and rangelands and how they are managed have created challenges around the application of the principles and process underlying both. First, commonly rangelands are made up of patchy, heterogeneously distributed vegetation heavily influenced by water availability including highly variable and often sparse rainfall. As a result, a rangeland management unit that includes adequate land and resources for a sustainable pastoral system to function is often large and cannot be easily divided into compartments or sections while a monoculture forest can, hence the need to work at multiple scales. Those scales include the landscape level, the rangeland management unit scale and also smaller local scales working directly with people on the ground managing parts of the silvopastoral systems, ensuring linkages and interactions between the two.

Second, in forest management, there is often the objective of raising income from selling timber or non-timber forest products, which can then be relatively easily divided between members of the forest management groups – often established as cooperatives to better facilitate this process. However, in rangelands raising income from the sale of rangelands products are rarely an objective: rather it is the livestock that is sold to raise income (and even here this may not be a priority). Livestock tends to be held by individuals or households and not the community, so any sales from these tend to go directly to the individual, creating less reason for establishing a rangeland cooperative.

This case study has been analysed under the conceptual framework (Figure 3) and the proposed criteria (Table 3) showing that PRM in a silvopastoral context provides an opportunity to improve the management of the land and resources while maintaining the flexibility that is required for optimizing the use of these mosaics and heterogeneous landscapes. At the same time, PRM can provide opportunities for raising income from non-timber forest products, increasing environmental services and producing more healthy livestock. Pastoralist communities will have a greater incentive to mobilize themselves into management groups and cooperatives and invest their own time and resources into improving land (and trees) management, raising opportunities for significant complementary pay-offs, both in terms of greater income, environmental services and more healthy livestock.

PRM opportunities for women's engagement

Silvopastoral lands generate many different uses and productions, relying on balance and controlled trade-offs between them for their sustainability. When one is prioritized over another, the system as a whole can be weakened. PRM provides an opportunity for bringing together different stakeholders and working through processes of negotiation and reaching an agreement over the use, management and governance of the land through a process of collective planning and decision-making. Issues such as access rights, grazing rotations, enclosures and sustainable

harvesting can be discussed and agreed upon. PRM has proven to be particularly facilitating for women – creating a space where they can contribute and lead. The establishment of women's leadership forums in the United Republic of Tanzania has been one successful approach encompassed by PRM that has proven successful in building women's capacity to do so. The Ujamaa Community Resource Team has been supporting the establishment of women's rights and leadership forums for raising women's voices and raising public awareness about women's rights. They also support women in obtaining individual land titles while building their capacity to participate in land management and governance processes. Impacts include changes in perceptions toward more positivity in women taking up leadership roles, an increase in the number of women leaders in villages and improved collective income generation. Further, it has been shown that the forums strengthen women's collective ways of working, group solidarity and status and they now feel more comfortable speaking up for their rights. The incorporation of women's rights and leadership forums in PRM processes has proven a powerful platform from which to support women's empowerment (Dungumaro and Amos, 2019; Ferrari 2021).

Reviewing the opportunities for implementing PRM in silvopastoral areas in West Africa

To date, PRM has been implemented in East Africa, where pastoral systems are more commonly found in grassland or shrubland-dominated rangelands rather than those with greater numbers of trees more suitable for silvopastoralism.

In 2021 a review was undertaken to assess the opportunities of applying PRM in Senegal and Mali. It concluded that there is considerable potential for testing and piloting PRM in both countries which, if successful could then be scaled up. In Senegal, a key issue is to clarify how PRM can add value to already established pastoral units and contribute to improved management or rangelands outside these. Pastoral units were set up in the 1980s and have since been supported by many projects. The pastoral units were established around water points to sustainably manage resources and spaces for the benefit of local populations and the community of transhumant pastoralists. However, they have been implemented in a top-down fashion and PRM offers a more participatory approach. In Mali, there is the challenge of identifying suitable areas that are manageable, as rangeland units are vast – and how best connections between these can be maintained. PRM provides opportunities for working at landscape and local scales to ensure that the vast rangelands are kept intact together with movement across them, while supporting local land users to improve management practices.

PRM can help bring a greater degree of community participation by including women and youth and in managing activities and interventions contributing to the GGW and other initiatives, where the mainly top-down approach to date has excluded communities and, in some situations, created conflict with them (Flintan,

Diop and Coulibaly, 2022). PRM can provide a space for all the community and other stakeholders to discuss and agree on issues such as where best to plant trees and how to best manage grazing around this. PRM can also provide an opportunity to ensure that adequate monitoring systems are in place so that the health of the rangelands including SPS is maintained. By building the capacity and willingness of communities to play a greater part in such initiatives, implementation will have long-term beneficial impacts, including reduced costs and greater sustainability.

For more information

2019 Review of PRM implementation (Flintan et al 2019).

Independent Impact Assessment Report: Participatory Rangeland Management (PRM) in Kenya and Tanzania.

www.greatgreenwall.org/about-great-green-wall.

Reversing, reviving and regenerating. How three pastoralist women are leading rangeland restoration in Kenya, Kyrgyzstan and Spain www.youtube.com/watch?v=eoVtpU1u5bo&t=12s.

CASE STUDY 16: UPDATES ON LEGAL SILVOPASTORALISM INSTRUMENTS IN LEBANON

Lebanon is situated on the Eastern coast of the Mediterranean Sea, in the Near East Region. The country has a total area of 10 452 km^2 (FAO, 2005). The topography is characterized by Mount Lebanon and the Anti-Lebanon mountain chains that run parallel to the coast and are separated by the Beqaa Valley. The ecological conditions of Lebanon are largely determined by topography and vary with altitude and exposition. The climatic conditions vary from Mediterranean climate along the coast and the mid-altitudes of the mountain ranges to subalpine or mountain Mediterranean climate on the highest slopes to arid steppes in the northern Beqaa plain. Rainfall follows a Mediterranean regime, with a long dry summer. The mean annual rainfall ranges between 700–1 000 mm on the coast, 900-1 400 mm on the western slopes of Mount Lebanon and 200-1 000 mm inland.

Forests and trees in Lebanon

The forests cover 136 500 ha and the other woodlands cover 106 000 ha, or 13.12 percent and 10.2 percent of the surface area of the country respectively. Coniferous forests cover an area of 43 936 ha, broadleaves forests 77 230 ha and mixed forests 15 282 ha. Other lands with trees (including fruit and olive trees) cover a surface of 113 000 ha or 10.8 percent of the surface of the country. The main species of Lebanon lands with trees are *Quercus calliprinos, Q. infectoria, Q. cerris, Pinus brutia, P. pinea, Juniperus excelsea, Cedrus libani, Abies cilicica, Cupressus sempervirens and Arceuthos drupacea.* The bulk of the forest area consists of oak and pine stands. Planted forests cover 10 500 ha, mostly *Pinus pinea* and other coniferous species.

Land tenure and legal context in managing the forests

Lebanon's Ministry of Agriculture (MoA) is the lead government agency entitled to the use, protection and management of forest resources. The Rural Development and Natural Resources Directorate at the Ministry of Agriculture is the national authority responsible for the development of the national strategy for the protection and management of forests and rangelands and is the key player in rangeland management on state and communal lands.

Land tenure management for grazing lands has two modalities, first the public, state-owned rangelands, which are rented by the government after submission of offers, giving permits based on technical specifications and a defined headcount, within a designated area and timeline; and second the communal rangelands, owned and rented by the municipality after the approval of the MoA of a few technical and administrative specifications. Both modalities need the municipalities' permission to grant the grazing time and targeted lands.

Although there are no specific laws in Lebanon regarding rangelands and their management, the Lebanese Forestry Code of 1949, which provides the MoA with the basis for forest management issues, is scattered among several laws, decrees and decisions.

This Forestry Law is the sole reference regarding rangeland management. However, the lack of adequate policies results in chaotic use of the land and consequently leads to conflicts between the different stakeholders, including the local communities. Besides, it makes it difficult for the municipalities and the Directorate of Rural Development and Natural Resources at the MoA to sanction people illegally using public lands. Hence, updating the existing policies, as well as establishing new policies on pasture management, should help to regulate this situation. In this context, FAO is supporting the Directorate of Rural Development and Natural Resources to revise, amend and update the forest law to meet the challenges facing the forest sector. Furthermore, a supportive legal framework of silvopastoralism is being suggested to complement this framework.

The current political strategy developed by the Ministry of Agriculture is intended to address these problems and improve the food security and livelihoods of pastoral peoples as reflected in key sections of the Forest Strategy (2020–2025), especially Pillar 2: Increasing agricultural production and productivity (including support for the adoption of good livestock practices and management) and Pillar 4: Improving climate change adaptation and sustainable management of agrifood systems and natural resources (including climate change adaptation, agrifood value chains and sustainable use of natural resources (soil, pastures, forests and fisheries).

Accordingly, the mandate of the Department of Rangelands and Public Gardens at the MoA encompasses four key tasks targeting rangeland management: 1) assessment of rangelands and inventory of forage species; 2) census and assessment of number and types of animals (specifically sheep and goats); 3) defining the carrying capacity of the country's rangelands; and 4) setting management plans to improve natural rangelands and increase their productivity.

Pastoralists have always existed in Lebanon but have been neglected, even considered enemies, by forest policies. The MoA has thus applied a forest policy pushing plantation and afforestation over large surfaces. This has led to conflict with pastoralists, especially those who were banned from traditional grazing areas. This approach is now changing, and policies have come to accept pastoralism as an alternative for rural people and dryland forests. Therefore, there is a need to improve rangeland management, aiming to sustain the people living around the forests, most of whom depend on livestock production.

Moreover, the Forest and Landscape Restoration Mechanism that was launched in 2014, managed to restore 1 000 ha of rangelands through participatory and gender-responsive planning, community-driven Forest Landscape Restoration (FLR) investments and sustainable economic alternatives developed at a landscape level. The selected two sites were located in Jered Tannourine and Manara; targeting two different types of ecosystems: Jered Tannourine site represents a natural mountainous land with little vegetation – scarce shrubs and almost no trees, whereas the Manara site comprises a typical grassland (where the soil is covered with an assembly of native annual plants that goats and sheep graze on), next to a degraded woodland and an area covered by oak trees. Recently, the initiative managed to support the ongoing review and updating of the Lebanese Forest and Rangelands Code.

Based on the success of different projects testing the new law, the MoA is also considering producing a national strategy for rangeland management aiming at sustainable large-scale rangeland management inside and outside forests – enhancing community engagement and accountability to ensure enhanced compliance with the Forest and Rangeland Law, and thus acknowledging the role of pastoralists in restoring the dryland forests and trees outside of forests.

Pastoralism practices in Lebanon

The Forestry Code (1949) lists technical and administrative mechanisms for the use of public rangelands under MoA supervision and granting grazing permission through regional forest centres. In the definition adopted by the MoA, pastoralism is referred to as a system and a mode of subsistence: "A life system that depends on raising animals on natural pastures and nomadism, with milk and animal products being the main source of food". Livestock production, and small ruminants in particular, plays an important role in supporting rural livelihoods in Lebanon, providing valuable products including meat, dairy and wool. Sheep and goat production relies on extensive systems making use of available range resources. The census of small ruminants counts around 930 000 head distributed all over the country, made up of 430 000 sheep and 500 000 goats (MoA strategy, 2008).

Livestock production is drastically changing today towards a more sedentary system, driven by acute rural migration and loss of interest among the younger generations. Grazing has always been an integrated activity in the communities living in marginal lands, while traditional transhumance is still practised to access different landscape resources. Shepherds rely on mobility to respond to changes

in water and feed resources through seasonal movements designed to reach better grazing areas and water points (Rugadya, 2013), but also as a tool for dealing with diseases, droughts and other environmental adversities. Livestock mobility can be vertical between the high mountains and the lowlands (this pattern is generally followed by goat herders) or horizontal (mainly with sheep herders) across different zones (Nori, Taylor and Semsi 2008). By sustaining such practices, the livelihoods of Lebanese pastoral communities are also sustained and subsequently, the patrimonial heritage of the rural communities is safeguarded (Chedid, 2014). Pastoralism in Lebanon is practised mainly in the semiarid and arid regions along the Lebanon–Syria borders where soil fertility is relatively low, although it is also present in forests and other wooded lands and the fertile Bekaa valley (ibid.). These grazing lands offer a wide variety of species distributed over different ecosystems and altitudes (ibid.).

This pastoral system adopted by Lebanese shepherds makes it one of the oldest, most resilient and most adaptive livelihood strategies, able to withstand environmental, economic and social challenges.

Legal reform is a step toward good governance

Analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that updating the legal instruments can shift the restoration and management diagram from a forest policy based on afforestation, toward the realization of the importance and interest of grazing inside and outside the forests. However, efforts should be made to develop participatory rangeland and forest management processes to address the challenges and inclusivity and participation of all stakeholders including pastoralists. The current political strategy developed by the Ministry of Agriculture is intended to strengthen community engagement and pastoralists' participation while promoting sustainable management of large-scale rangelands inside and outside forests.

The participatory perspective will increase the engagement of communities and civil society's engagement to ensure enhanced compliance with the Forest and Rangeland Law, hence to ensure that their voices are heard.

Finally, two last considerations need to be accounted for during this development. First, further coordination between Forestry and Animal departments is necessary to apply the multidisciplinary perspective and policies. Second, there is an unavoidable need for improved data, concerning not only the number of animals and their breeds, but also lands grazed, stock density, movements and grazing pressure on different lands and at different times of the year. This information is absolutely necessary for the nationwide assessment and management of rangelands.

For more information

FAO (2010) Global Forest Resources Assessment 2010. Country Report: Lebanon.
Ministry of Agriculture. Lebanon National Agriculture Strategy (NAS) 2020-2025

CASE STUDY 17: SILVOPASTORAL STRATEGY FOR MOROCCO

The geographical location of Morocco in the northwestern corner of the African continent and its topography explains its wide diversity of ecological conditions. The country is characterized by a variety of terrestrial ecosystems and includes four of 14 terrestrial biomes, with some critical and endangered ecoregions listed in the World Wildlife Fund Global 200 list (Dinerstein *et al.*, 2017). It is one of the most diverse countries in the Mediterranean region in terms of vegetal species. Natural vegetation in the forest domain is diverse and covers an estimated area of 9 million ha of which 5.8 million are forests and the remaining 3.2 million are dominated by alfa grass (*Stippa tenacissima*). The main naturally occurring tree species are holm oak (*Quercus ilex*), argan (*Argania spinosa*), cedar (*Cedrus atlantica*), Berber thuya (*Tetraclinis articulata*), cork oak (*Quercus suber*), acacia (*Acacia* spp.), pines (*Pinus* spp.), woodlands and maquis. Other exotic tree species, such as *Eucalyptus* spp., have been planted.

Moroccan forests, which are generally referred to as dryland forests and silvopastoral systems, play a crucial role in rural area development through their production of goods and ES. Such roles include supporting services (ecosystem and population processes); provisioning services (food, water, wood and so on); regulating services (regulation of climate, water, disease and disturbance regimes); and cultural services (aesthetic and spiritual benefits, cultural identity and recreation/tourism) (Croitoru and Merlo, 2005). The legal framework allowed some special entitlements for people called "use-rights holders" living near forest domains. The most important entitlement is the right to free graze their domestic livestock and the combination of grazing with trees.

Silvopastoralism in Morocco

Silvopastoral in forest lands is a legacy of well-adapted practices. Indeed, in inland mountainous and nearby forest areas characterized by physical and environmental fragility, traditional production systems focused mainly on the use of natural resources. Local populations developed traditional sustainable systems to deal with resource scarcity (water and land) and regulate natural resource uses. Such systems are based on diversification, mobility and local social institution/authority in charge of customary rights application. Rights define access conditions, right holders' status, uses and/or a prohibition on common resources and social actions and against users violating rules. Social organization and rules were the main pillars for reconciling social needs and environmental requirements for the maintenance of renewable resources and biodiversity and dealing with harsh conditions.

Nowadays, forests remain the main livelihood provider for rural households. The forest sector has always been an important contributor to Morocco's economy and provides a source of economic and social benefit to rural communities (ibid.). Through their leaves, fruits and associated herbaceous strata, the forest ecosystems contribute significantly to national livestock production, from which a vast majority of the rural population obtains almost all its income directly or indirectly. 30 percent of small ruminants in the country in addition to camels in southern

Morocco, depend on free silvopastoral resources and graze between eight and 12 months per year within the forest domain (Bourbouze, 2006). As rangeland, the Moroccan forest produces 1.5 billion Forage Unit in year-1 (i.e. 17 percent of the national forage assessment) and provides shelter and a place to rest for livestock.

Challenges and issues of silvopastoralism in Morocco

Over the years, most of the customary principles underlying common resource uses (forest and silvopastoral resources) have been undermined. The right to use common resources as an attribute of social members belonging to a social group has come up against increasing individualism and a growing capitalist mentality. Furthermore, many changes in demography, urbanization and settlement instead of mobility, climate, technology, economy, society and politics have intensified a variety of natural resource crises, mainly common land resources reduction for intensive production and human settlement leading to excessive livestock grazing. Grazing has become a widespread practice affecting the forest domain and threatening the sustainability of Morocco's forest and natural ecosystems (Moukrim *et al.,* 2019). Within such a dynamic, forests as grazing land resources have been progressively moving from a common resources pool toward open-access spaces.

Moreover, socioeconomic changes promoting sedentarization and restricting social movement have caused a shift from nomadic to sedentary lifestyles and increased the concentration of livestock for long periods and within smaller spaces. Grazing also represents an opportunity that encourages urban dwellers to invest their money in this sector by buying livestock to be kept by a tenant, neighbour or acquaintance in the countryside. In addition, climatic conditions such as the scarcity of precipitation affect also negatively the performance of Moroccan agrosilvopastoral systems.

The combination of aforementioned changes, the loss of ancestral management practices, the frequent unsustainable use (i.e. open access: Hardin 1968), the lack of cooperation among users and the lack of local community involvement are leading to a grazing pressure which is at levels far beyond the forestland's carrying capacity throughout the country. Such pressure is threatening the sustainability and viability of dryland forests through a lack of forest regeneration and has been described as the main cause of vegetation loss and land degradation and a major threat to the sustainability of the country's dryland forest ecosystems as it impedes their regeneration and the efficacy of reforestation programs. Therefore, it seriously increases soil erosion (Steinfeld *et al.,* 2006), extending siltation problems within waterways and dams. It also erodes biological diversity (Alkemade *et al.,* 2013), threatens human life and civilization (Wodon *et al.,* 2014) and leads to a hazardous future for forest resources (IPCC, 2014). The problem of overgrazing is multidimensional and multiactor, with a lack of common vision between the different partners. Dealing with such pressure has been based initially on disparate initiatives and pilot projects in limited areas.

To find sustainable solutions to restore and manage the silvopastoral resources and to reconcile trees and grazing livestock in forest ecosystems, a silvopastoral strategy has been developed by the Moroccan Forestry Department, which is the major institutional actor of governance in forest areas, in collaboration with the partners concerned by this question (in particular: the Ministry of Agriculture, the Ministry of the Interior and users of local population organizations).

Strategy development process and its vision

The development of this silvopastoral strategy has required a participatory approach (*Alkemade et al*, 2013). The project's stakeholders (Department of Water and Forests, Ministry of Agriculture, Ministry of Interior, National Agencies, etc.) and several actors (user communities and civil society) were engaged in the reflection on its design and mode of implementation, involving interviews, focus groups, workshops, meetings and/or advisory committees. The work approach, which was carried out in several phases, is described as follows: i) development of a precise silvopastoral diagnosis; ii) capacity building in strategic planning to ensure a solid institutional anchoring; iii) organization of interactive workshops (with partners and civil society) for strategy formulation; iv) sharing workshop results with managers for a uniform understanding of the orientations of the new strategy; and v) formulation and restitution of the strategy in a simplified and well-structured way ensuring the visibility and readability of its content.

After a long process of consultation and participation, the national silvopastoral strategy was developed in late 2016. Its vision is that silvopastoral resources are restored and managed sustainably and effectively in the long term through good governance of all the goods and services of these spaces, in the interest of: i) the socioeconomic well-being of the population; (ii) biodiversity conservation; and (iii) climate change mitigation and combating land degradation.

The construction of this national silvopastoral strategy integrated the visions of the various institutional partners. Such integration can only be effective within a unifying framework within which each stakeholder will act according to their missions, resources and responsibilities by converging towards a single and harmonized objective.

The strategic framework developed and validated in late 2021 will help to better manage the silvopastoral resources, matching the threshold of what the land can provide in the long term. Finally, the strategy combines the interventions of various institutional partners as well as civil society and community and pastoral organizations, developing an adequate framework for bringing together all partners in a complementary approach.

Objectives and strategic axis of the silvopastoral strategy

The silvopastoral strategy aims to ensure that silvopastoral resources are restored and managed sustainably and effectively in the long term. This strategy deals with questions relating to the restoration of natural ecosystems in the context of climate change, governance, access to resources, the revival of pastoral practices

and capacity building at the local level. The main strategic axis of this framework are: i) reconstitution of silvopastoral ecosystems; ii) improving the organization of users of silvopastoral resources; iii) support for the socioeconomic development of forest and nearby forest areas; (iv) improving the governance of silvopastoral resources; (v) promotion of holistic and dynamic research and development; and vi) strengthening the technical and organizational capacities of the Moroccan Forest Department.

Strategy operationalization in restoring the dryland forests

In-depth analysis of this case based on the conceptual framework (Figure 3) and the proposed criteria (Table 3) shows that this silvopastoral strategy deals with questions relating to the restoration of natural ecosystems, governance and access to resources, the revival of pastoral practices and capacity building at the local level in this context of global change. The development of the common vision for the management of forest rangelands between the different partners was a success. Resulting from a long participatory process, the silvopastoral strategy has a common and accepted vision to restore and sustainably manage silvopastoral resources in the long term through good governance of all goods and services provided by these spaces. As the implementation of the strategy is the responsibility of the Forest Department, piloting the strategy would benefit the evaluation and adjustment processes. In this sense and to improve efficiency during the generalization phase in the other Moroccan regions, a regional silvopastoral strategy and a first territorialized action plan were developed and validated in 2021 by the Ministry in close coordination with communities and related stakeholders to better restore ecosystems and sustainably manage the silvopastoral resources in this context of climate change.

For more information

http://www.eauxetforets.gov.ma/Pages/Publications.aspx

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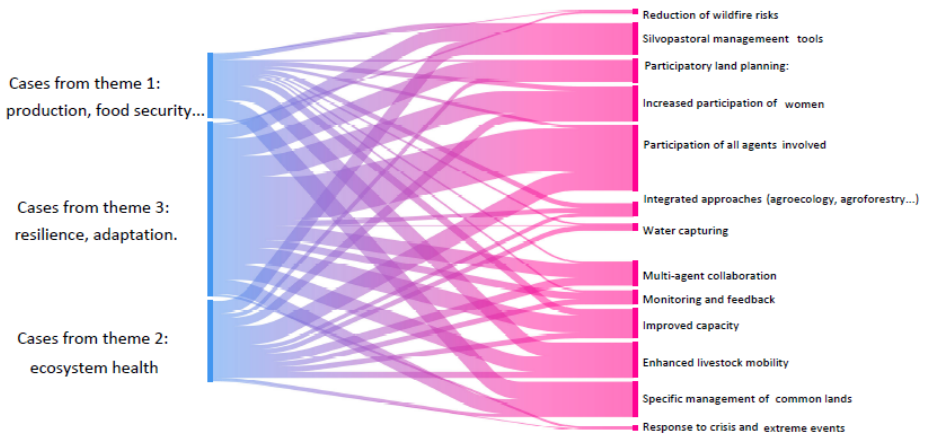
Chapter 4: Discussion: Applying a conceptual framework where grazing with trees improves dryland silvopastoralism

The case studies presented in the three themes demonstrate that silvopastoralism could be an instrumental consideration for landscape restoration, sustainable land management, and halting desertification, while protecting local livelihoods. However, it is clear that understanding the interactions between people, trees and livestock in SPS is crucial to improving their governance and multifunctionality. Hence, the discussion section exploits the synergies and trade-offs presented in the three themes to identify the key lessons learned and define the path forwards in integrating forest, trees and livestock. (Chapter 5).

FIGURE 18
shows the references to the 10 most cited land management-related issues. Each item's width is proportional to the number of mentions it received. (Sankey Diagram performed with Atlas.ti Software)


Cases from theme 1: production, food security...
Cases from theme 3: resilience, adaptation.
Cases from theme 2: ecosystem health
Reduction of wildfire risks
Silvopastoral managemeent tools
Participatory land planning:
Increased participation of women
Participation of all agents involved
Integrated approaches (agroecology, agroforestry...)
Water capturing
Multi-agent collaboration
Monitoring and feedback
Improved capacity
Enhanced livestock mobility
Specific management of common lands
Response to crisis and extreme events

Source: Elaborated by authors

Lesson 1: Multifunctionality is a key property of silvopastoral schemes, generating diversified products and aspiring to high quality rather than to maximize production

The case studies show that silvopastoral production plays a strategic role not only in the nutrition of pastoral households – providing an opportunity to optimize the intake of terrestrial animal food source (FAO, 2022) especially in marginalized dryland-based communities – but also in their economy and resilience. Specifically, livestock production, through its market value, allows households to access food and everyday consumer goods, while forest products become key assets for silvopastoral communities as shown in several cases (Brazilian Caatinga, Chilean transhumance). Moreover, the combination of different cycles of production with different incomes makes diversified production, hence multifunctionality, a way to stabilize production and ensure the long-term sustainability of silvopastoral producers.

Silvopastoral management is thus better focused on top-quality diversified multiproduction, dealing with different resources in flexible mode, relying on high-biodiversity-based conditions and applying a variety of strategies, including pastoralism.

Lesson 2: Integrated and participatory land planning and management contribute to increase the benefits from silvopastoralism, strengthening the governance structure

Rising individualism, lack of cooperation and community involvement, the loss of ancestral practices and the weakness of local governing institutions are hampering the governance of silvopastoral lands. In many places, customary principles underlying the use of forests and rangelands have been undermined and group identities provided by the commons have faded as a result of globalization. However, several case studies using collaborative and participatory multistakeholder frameworks are improving silvopastoral governance, contributing to controlling degradation processes and restoring the land. Collaborative frameworks should acknowledge the role of women and other groups and be supportive of their capacity for action.

Most of the case studies – and specifically the West African case on participatory rangeland management – depict local participation as the keystone for silvopastoral governance. Grassroots and civil organizations are instrumental in articulating this participation, especially when the current situation often demands hybrid solutions involving both customary and state institutions.

Lesson 3: Efficiency criteria should be acknowledged at every stage of silvopastoral activity, from breeding to markets

Most of the cases acknowledge the growth in livestock numbers correlated with population growth, even in conflict areas, as in the South Sudanese case, which is harming pastoral and silvopastoral livelihoods. Although livestock products are used almost exclusively for household consumption in the Chilean and South

Sudanese cases, many silvopastoralists, including Brazilians and Kenyans, need their products to reach urban markets. In addition, genetic selection according to silvopastoral specificities, the availability of key infrastructures or management skills, should be taken into account to ensure production performance, as shown by the Brazilian case. The South American and African case studies show transferable examples of improving value chains, providing greater opportunity for their products, raising income from timber and NTFP and potentially giving communities more incentive to actively participate and invest in the collective management of their land base.

Lesson 4: Secured mobility is at the heart of management and resilience of silvopastoralism

Pastoral mobility remains one of the main adaptive strategies of pastoral and silvopastoral systems in response to the spatiotemporal variability of rainfall and resources. In addition, mobility is also the key tool for silvopastoral land management, as mobile livestock can be applied in any patch of land demanding intervention. Mobility helps livestock keepers build economic networks over a larger geographical area and therefore adapt better to climatic or economic shocks. Mobility is also the key for most of the innovations that could make silvopastoralism an asset in land restoration, such as programming grazing or managing mosaics where pastoral mobility holds a multifunctional interaction between different areas and land uses. Mobile livestock provide services to farmers through manure, traction, or participating in the dynamism of the markets, attracting traders and promoting the circulation of money. Securing mobility, therefore, contributes to the maintenance of the different functionalities of silvopastoral activities. However, agricultural land is expanding at the expense of rangelands or fallows. Urbanization and mining activities can also have a strong impact on pastoral activities. As shown in the Chilean case, transhumance and its corridors are threatened by this transformation and the same phenomena can be seen at local scale damaging ancestral paths and depriving the use of traditional grazing lands.

Lesson 5: Planned and rotational grazing is an alternative to free-range grazing which leads to degradation.

The effects of grazing and vegetation management on the composition and structure of dryland ecosystems species vary from site to site, demanding context-specific assessment and interventions. Grazing can be a valuable tool to maintain and enhance dryland health, but its mismanagement can spread land degradation, driven by inappropriate policies, reduction of grazing areas, disruption of livestock mobility, reduced access to water, land encroachment, and so on. Despite the different grazing management aspects shown in the case studies, overgrazing poses a real threat and plays an active role in degradation, overriding the positive effects of trees (Lulandala *et al*., 2021). Conversely, undergrazing can also have strong degradation effects such as biomass accumulation in forests, reduced basal

cover, inhibition of primary production and increasing climatic and fire risks.

It is therefore crucial to encourage management practices that control grazing pressure and adapt it to the natural cycles of local vegetation. Thus, when the estimation of optimal stocking rates at each moment of the year is applied to local practices, it can be a step toward halting land degradation, as shown by the Tunisia case study. Sustainable grazing regimes with tight animal control and proper resting periods for each type of land managed, as depicted in the Spanish or Senegalese case studies, for instance, along with rotational and target grazing or holistic management, are more effective in providing priority ES.

Lesson 6: Community-based management is crucial to identify, balance and minimize the trade-offs while optimizing the diversity of resilient production.

Active management is key to ensuring the performance of SPS, and evidence from the Tunisia case study shows how key benefits result from grazing regimes, implementation of soil and water conservation measures, reseeding with legume forage species or planting shrubs and trees. Previous lessons have highlighted critical trade-offs managed by silvopastoralists, including managing tree cover with grass cover, and grazing intensity with pasture resting. A similar trade-off may need to be managed between grazing and soil organic carbon (SOC). A sound strategy for climate change mitigation consists of managed grazing regimes and intensities favouring SOC storage in soils through reduced compaction and degradation, while enhancing above and underground vegetation growth as shown in the Senegal, Tunisia and Uzbekistan cases. Grazing practices that promote soil carbon sequestration include rotation, legume additions, improved nutrient management and other silvopastoral practices (including modern silvopastoral designs).

Lesson 7: Co-production and improvement of silvopastoral knowledge, a requisite for the promotion of sustainable investments in silvopastoralism.

The development of silvopastoralism requires an alliance between the endogenous knowledge of producers and scientific research. Research and development projects are increasingly turning to co-learning, co-construction and co-development approaches. FAO's Pastoralism Knowledge Hub is a good example of an association between producer organizations, development actors and research organizations. This mutual support requires a rethinking of the main principles of participation in projects, incorporating empowered and capacitated grassroots organizations and making accessible quality information on the possibilities of development of the transition towards silvopastoralism.

However, certain knowledge gaps need to be filled. Specifically, there is an urgent need to collect field data about the number of grazing animals, the type of lands grazed, the stock density and pressure and movement in different lands and at different times of the year. This data is vital as shown by the Jordan, Lebanon and Morocco cases. Field schools directly involving agropastoral producers are

an interesting initiative to promote continuous training for populations that are often far from the decision-making circles and a way to disseminate silvopastoral knowledge and research innovations. These field schools promote inclusive knowledge, but also peer-to-peer learning, experience exchange and networking.

Lesson 8: The adaptive capacity of silvopastoral lands and their communities in facing the climate change and other crisis provides a path to improved resilience.

Adaptation is key for survival, and local communities use pastoralism, along with management of forests, trees, soil and water as their main adaptation tools. Silvopastoralists rely on moving, trading or exchanging their livestock when conditions become too harsh, for instance shifting from lowlands to highlands, from wet season to dry-season grounds, from grassland to forests, as a mechanism to overcome agroenvironmental constraints. Improved adaptation means improved livelihoods, enhanced resilience and a higher capacity to benefit from markets and innovation.

Lesson 9: Land tenure and rights considerations are instrumental elements in the territorial dension of silvopastoral systems

Silvopastoralism is often developed, at least partially, in common and state-owned marginal lands holding key assets for feed and adaptation. These lands contribute to the survival of people and communities who do not hold secure rights over them but nevertheless depend on their resources. Private property is often absent or limited to a few housing areas and fields. Thus, the idea of scaling up innovative solutions to improve the ecological, social and economic role of silvopastoralism requires addressing the question of more secure land tenure. The management and governance of rangelands often remain in conflict when formal and customary rights are differently recognized in different countries and regions.

The case studies show how promoting silvopastoralism with land that is not individually owned requires the articulation of individual farming practices with collective management activities. Articulating common property and individual ownership has consequences for actors' investment strategies. Livestock remains an object of rural capitalization while pastureland and natural resources require multiactor coordination in investments.

Lesson 10: Flexible, updated and ambitious policies and regulations towards supporting silvopastoralism are deeply needed to protect sustainable management and governance

Forestry policies have tended to promote afforestation over large dryland surfaces and banned grazing, neglecting the key role of woody vegetation in pastoral systems. In terms of restoration, biodiversity conservation and fighting climate change, tree planting is a dilemma. Simply put, massive tree planting could be useless in restoring ecosystems or fighting climate change and may even be harmful to the environment. Bad choices about tree species, plantation site,

plantation parameters and management could increase global warming, detract water from the ecosystem, exacerbate wildfire risk and devastate wildlife. Thus, afforestation is not always a good idea (Davis and Robbins, 2018), neither is the forest model used as future scenario viable in many areas, especially in drylands (Vetter, 2020).

Grassland scientists and producers have defended alternative ways to address carbon storage and regenerate biodiversity based on improved management of rangelands (Veldman *et al*., 2015). Silvopastoralism can help to clarify the middling path as trees are needed for all functions but so are shrubs and grasses and multifunctional lands. Silvopastoralists have built and co-evolved with open forests providing key services, simultaneously managing different patches of land – both forested and treeless. Their designs and management systems can improve the way trees are selected, planted and managed in dryland upon their multifunctionality and provision of services. Such an approach can adjust tree structural parameters (such as height, cover or shape) to optimize their performance and modulate their diversity upon their expected functions and outcomes. Meanwhile, the open forests, savannahs, mosaics and even individual tree elements included in grasslands and open landscapes have proven to be extraordinary assets in regenerating ecosystem functions, while keeping those lands rich and productive. Sharing the path with silvopastoralists, new and successful tools to restore dryland ecosystem can thus be developed, though the result will not be any form of idealized dense forest.

Fortunately, the tide is turning with key advances for the silvopastoral approach. Several concerned governments, such as Lebanon and Morocco, are developing silvopastoral policies and strategies, combining the interventions of the various institutional partners as well as civil society and pastoral organizations in delivering a shared vision and adequate policy development frameworks. People are allowed to graze their livestock even though pastoralism and forestry have often been considered at odds with one another.

Agricultural policies are recognizing pastoralism as an alternative for rural people, while forestry policies are shifting from pure afforestation approaches towards mixed approaches, arranging for grazing inside and outside the forests. Accordingly, there are renewed efforts to gather information, collect data, assess the real potential of rangelands and land with trees, implement demonstrative projects, engage stakeholders and promote sound governance tools. Governments become key actors as the authorities responsible for the development of policies and strategies alongside municipalities, stakeholders and local communities.

From the above discussion, silvopastoralism is emerging not only as a nature-based (and people-based) solution, but also as a new approach to managing land in an integrated way. This paper originally intended to integrate forestry and pastoralism, but ended up integrating productivity and regeneration, livelihoods and ES, and both local needs and global priorities. As local people's engagement, work and skills constitute the rudiments of successful silvopastoral initiatives, they should not only be consulted, but incorporated into any decision-making process.

Chapter 5: The way forward: the need to accelerate effective holistic transition actions

The planet's homeostasis, which makes human life viable, is being stretched to its limit. The FAO 2018b report, *World Livestock: Transforming the Livestock Sector through the SDGs*, shows that converting other ecosystems, especially forests, to produce fodder will have serious repercussions on people and the environment. This is especially true since approximately one-third of the world's cropland is being used to grow animal feed (FAO, 2018b; FAO 2020). While under- and overgrazing can lead to desertification, shrub encroachment and lower biodiversity levels, indeed, rehabilitating degraded lands and creating expansive agroforestry with better grazing management can boost agricultural productivity, increasing its surface by another 1 billion hectares (FAO, 2022a; HLPE, 2019).

Therefore, there is – more than ever – a need to adopt an integrated holistic-transition approach to better grazing with trees and improving agrifood systems. A clear example of this situation is the controversy between grazing and afforestation, as explained in this forestry paper: they are compatible under a holistic approach, but when uncoordinated they tend to cancel each other out. Similarly, when trying to address simultaneously different ES without a clear priority and management path, the result could be counterproductive, such as banning grazing to increase vegetation cover, which can increase the risk of wildfires and end up with the site being completely destroyed.

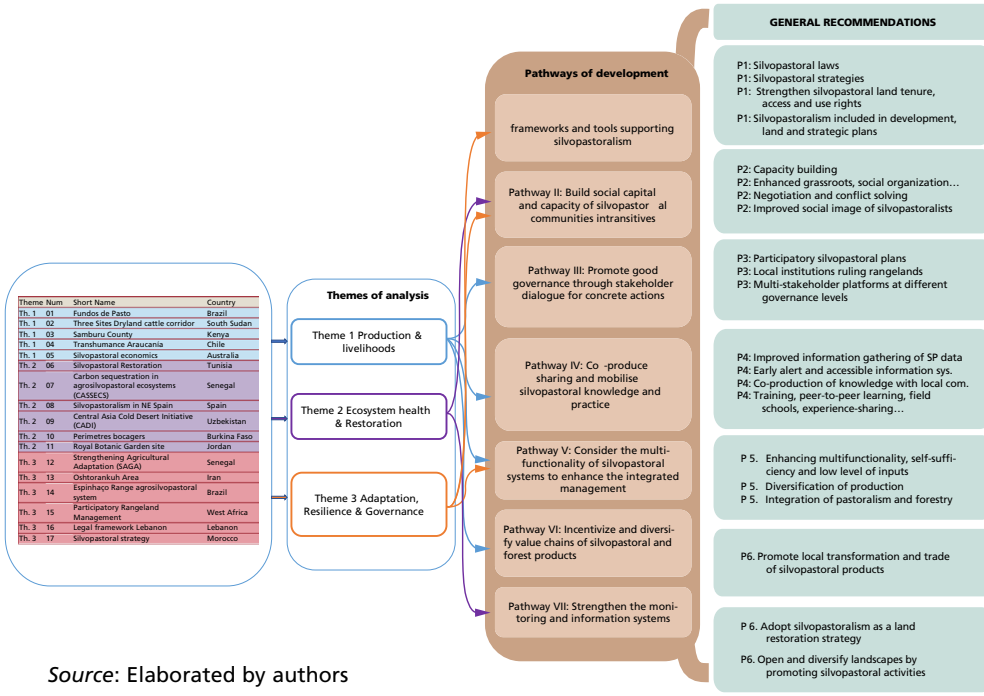
The UN Food Systems Summit, held in September 2021, highlighted the importance – under Action Track 3 "Boost nature-positive production" – of making livestock nature-positive and more resilient to shocks and proposed innovations to halt deforestation and reduce emissions from livestock, thus mitigating climate change (United Nations, 2021).

The collected pieces of evidence in this paper highlight that silvopastoralism is one of the most innovative solutions in drylands as it plays a compelling role, not only in improving productivity and income but also protecting the soil from further degradation and improving soil sustainability and other ecosystem features. Moreover, silvopastoralism has evolved in drylands and co-evolved with its ecosystems, as a climate coping and risk management system, to maintain production and natural resources even in the occurrence of droughts periods and extreme weather conditions (Soni *et al.*, 2016).

As shown in Figure 19 below, building on the collected evidence and available research has undoubtedly helped to draw the path forward towards holistic –

transition actions. Specific transition actions in this section list some of the key considerations that a sustainable, multifunctional and productive silvopastoral management initiative should take into account to generate the desired forest restoration and management outcomes. Few practical recommendations have been issued, as they tend to be dependent on local conditions and culture and have been remarked in each case study. However, some lessons emerge as a common path for developing silvopastoralism management in drylands: diversified productions and multifunctional landscapes; multi-agent and collective action; integration of forestry, agriculture and livestock farming under agroecological principles; territorialization and self-sufficiency and balanced trade-offs. The adaptation of these paths to each territory is a task that should be accomplished locally but legally, technically and politically supported by different levels of government, research and expertise.

FIGURE19
The interaction process from the collected evidence to the proposed holistic transition actions.


Theme Num Short Name Country
Th. 1 01 Fundos de Pasto Brazil
Th. 1 02 Three Sites Dryland cattle corridor South Sudan
Th. 1 03 Samburu County Kenya
Th. 1 04 Transhumance Araucania Chile
Th. 1 05 Silvopastoral economics Australia
Th. 2 06 Silvopastoral Restoration Tunisia
Th. 2 07 Carbon sequestration in agrosilvopastoral ecosystems (CASSECS) Senegal
Th. 2 08 Silvopastoralism in NE Spain Spain
Th. 2 09 Central Asia Cold Desert Initiative (CADI) Uzbekistan
Th. 2 10 Perimetres bocagers Burkina Faso
Th. 2 11 Royal Botanic Garden site Jordan
Th. 3 12 Strengthening Agricultural Adaptation (SAGA) Senegal
Th. 3 13 Oshtorankuh Area Iran
Th. 3 14 Espinhaço Range agrosilvopastoral system Brazil
Th. 3 15 Participatory Rangeland Management West Africa
Th. 3 16 Legal framework Lebanon Lebanon
Th. 3 17 Silvopastoral strategy Morocco
Themes of analysis
Theme 1 Production & livelihoods
Theme 2 Ecosystem health & Restoration
Theme 3 Adaptation, Resilience & Governance
Pathways of development
frameworks and tools supporting silvopastoralism
Pathway II: Build social capital and capacity of silvopastor al communities intransitives
Pathway III: Promote good governance through stakeholder dialogue for concrete actions
Pathway IV: Co -produce sharing and mobilise silvopastoral knowledge and practice
Pathway V: Consider the multi-functionality of silvopastoral systems to enhance the integrated management
Pathway VI: Incentivize and diversi-fy value chains of silvopastoral and forest products
Pathway VII: Strengthen the moni-toring and information systems
GENERAL RECOMMENDATIONS
P1: Silvopastoral laws
P1: Silvopastoral strategies
P1: Strengthen silvopastoral land tenure, access and use rights
P1: Silvopastoralism included in development, land and strategic plans
P2: Capacity building
P2: Enhanced grassroots, social organization…
P2: Negotiation and conflict solving
P2: Improved social image of silvopastoralists
P3: Participatory silvopastoral plans
P3: Local institutions ruling rangelands
P3: Multi-stakeholder platforms at different governance levels
P4: Improved information gathering of SP data
P4: Early alert and accessible information sys.
P4: Co-production of knowledge with local com.
P4: Training, peer-to-peer learning, field schools, experience-sharing…
P 5. Enhancing multifunctionality, self-suffi-ciency and low level of inputs
P 5. Diversification of production
P 5. Integration of pastoralism and forestry
P6. Promote local transformation and trade of silvopastoral products
P 6. Adopt silvopastoralism as a land restoration strategy
P6. Open and diversify landscapes by promoting silvopastoral activities

Source: Elaborated by authors

The last section of this technical report lists and summarizes some of these transition paths, recommending that they be collective, transversal and as multifunctional as the systems they try to mainstream and upscale. Those paths focus on different aspects that should be managed either sequentially or simultaneously depending on the degree of maturity that the process has reached in each territory.

Path 1: Develop forest-related legal frameworks and tools to support silvopastoralism

Too often, forest regulations consider livestock and grazing activity as detrimental to forests. These activities have been limited and banned on the premise that they damage vegetation. Conversely, silvopastoralist strategies are particularly relevant in dryland areas with forests, woodlands and mosaics of different land uses and tenure schemes. These complex areas are the most suitable territories to develop silvopastoral strategies, presenting a method of unifying efforts to boost sustainability and land degradation neutrality.

In summary, facilitating the transition from forest policies just focused on afforestation, toward integrating sustainable grazing management inside and outside the forests requires the following:

- develop participatory silvopastoral policies and strategies at different levels, including transboundary and international agreements;
- design adequate grazing strategies to incorporate into forest management;
- secure and balance the use and access of crop, pastoral and forestry areas within laws and regulations governing land tenure; and

ensure legal frameworks supporting pastoralism under the previous conditions.

Path 2: Build social capital and capacity of communities to develop silvopastoral initiatives

Silvopastoralists and agrosilvopastoralists with small herds and few land rights are often marginalized in participatory processes and policies, as they are difficult to reach and engage in standard participatory planning and management processes. The recommendations contained in this path seek to reinforce the social capital of silvopastoralists and ensure their participation in the development of silvopastoral initiatives, balancing their views alongside other local participants.

In summary, facilitating the transition towards a social capital and capacities of silvopastoral communities requires the following:

- improve the image and social perception of silvopastoral activity and silvopastoralists;
- build awareness, capacity, engagement and social skills of silvopastoral communities and institutions through specific programmes;
- facilitate, give support and assign resources to silvopastoralists' associations and institutions so they can be self-represented in any initiatives involving silvopastoralism; and
- promote the constitution and functioning of specific silvopastoralist organizations: grassroots, commercial networks, women's organizations; and
- prioritize marginalized groups of silvopastoralists, including no-land pastoralists, women, young people, employees and low-income individuals in silvopastoral planning, as they are often in charge of the marginal, most sensitive and degradation-prone lands being often held responsible for their degradation.

Path 3: Promote good governance through stakeholder dialogue for concrete actions

Policies, planning and governance are key to making desired scenarios a reality. Optimizing silvopastoral governance can be achieved through the participatory building of sound planning and governance instruments and institutions. The specific recommendations included in this section highlight the importance of silvopastoralism-oriented management plans, generated under participatory frameworks that develop multipurpose governance and land sustainability goals, which balance trade-offs, therefore addressing land degradation neutrality and enhancing ES.

Participatory processes enable sound development, implementation and monitoring of legal tools and planning instruments related to sustainable land use. In the case of silvopastoralism, this means incorporating both foresters and agro- and silvopastoralists into the participatory frameworks, processes and institutions ruling those initiatives. Encouraging the participation of silvopastoral communities means not only acknowledging the different roles and incorporating their players into decision-making but also adapting tools, spaces, schedules and information flows to their needs, building their capacities and applying a gender-sensitive approach. The human factor is key to the management of silvopastoral systems and a top priority when designing and implementing planning and governance instruments should be carefully mapping, incorporating, capacitating and training the different groups of people involved in their development and governance.

Furthermore, restoring traditional institutions ruling pastoralism in different lands – for example, the *hima* and the North African *agdal* systems discussed in Chapter 4 – and building on them through participatory frameworks, technical skills and support and necessary resources ensures the right governance of silvopastoral systems and enables them to thrive.

Good economic performance and valuable outputs for stakeholders are the keys to a long-term, sustainable system. Accordingly, a governance framework is needed where the interests of all these stakeholders and potential trade-offs are represented and could be balanced with other interests. The autonomy and capacity of action of the participatory bodies or councils holding decision-making in those initiatives along with their accountability will lead the way towards the successful management of silvopastoral dryland.

In summary, facilitating the transition towards the good governance path requires the following:

- introduce forest products as an incentive for restoring silvopastoral lands involving the collaboration of both foresters and livestock producers;
- design and implement feed and water scarcity adaptation strategies specifically when facing droughts;
- develop equitable and inclusive gender-sensitive planning and management strategies to promote silvopastoralism;
- develop sound participatory grazing and silvicultural management plans to ensure the provision of ES and balance the trade-offs;

- provide local communities with facilitation, conflict-solving and technical support to collectively respond to new challenges; and
- build working participatory governance institutions drawing from traditional mechanisms and knowledge and complement them with technical and scientific support from government and academia.

Path 4: Co-produce and mobilize silvopastoral knowledge and practice

Many of the successful approaches to managing complex agroforestry landscapes come from traditional knowledge. This paper recommends that research and development projects in the areas of silvopastoralism incorporate traditional local solutions and build upon them with new and accessible technologies. Integrating both these sources of knowledge by taking into account local capacities and practices and enriching them through research, technologies and networking is essential to implementing adaptive management systems.

This integration of knowledge is addressed in these recommendations through a training-experience-action sequence. Training is linked to the strengthening and dissemination of knowledge among practitioners and action to apply knowledge to the diversification of production and the other topics addressed by the by this paper. Permanent interaction between integration, training and action at the local level encourages increased innovation and further improvement of practice, complementing local knowledge with skills acquired through training, coaching and community exchange visits. This also implies the engagement of practitioners in the research, dissemination and training initiatives aiming to upscale the silvopastoral approaches. The ultimate goal of recommendations is that silvopastoral systems benefit from this integration, supported by the organization and social capital of local communities (producers' organizations; grassroots), local governments, academia, researchers and experts.

This 'multiagent' co-production of knowledge, which brings together the knowledge of local communities, researchers and technical experts to devise strong silvopastoralist systems, places a heavy emphasis on participation. This echoes the previous pathway, which highlighted the need for participatory planning and policymaking in projects. However, two main challenges must be noted when adapting this approach to silvopastoralism.

The first is the special conditions in which the activity develops, with mobile animals and people and a wide array of different disciplines converging in the same production unit. These particularities increase the complexity of designing and implementing good networks and platforms that are suitable and useful for silvopastoralists. The team designing the project should adapt to the conditions and needs of the practitioners and work effectively to make the different collectives involved compatible. This stage of the process can be long and fruitless, spending time and resources deeply needed for other tasks. However, a successful preliminary work of mutual engagement and co-adaptation among the different people concerned will in the end contribute greatly to the process performance.

The other challenge concerns knowledge and practice. In silvopastoral systems, certain traditional skills are learned and transmitted over generations from practitioners to apprentices and are often held by elders and others who are at risk of losing this knowledge. Many of these skills are underestimated but may turn out to be invaluable when dealing with specific landscapes. It is therefore vital to involve the people with these skills in the project, encouraging them and enabling them to pass on their knowledge. Another key part of co-producing knowledge involves discovering, analysing and considering skills and collaboratively find ways to keep them useful for the future.

In summary, facilitating the transition to mobilize the local and traditional knowledge path requires the following:

- improve knowledge of silvopastoralism with sound data about the production, stocking rates, schedules and land use characterize silvopastoral activity around the world;
- promote participatory and multiagent initiatives of co-production of knowledge engaging practitioners, academics, specialists and policymakers;
- develop silvopastoral training programmes based on co-produced knowledge, experience sharing and peer-to-peer learning to acquire the skills and capacities needed to run a climate risk mitigation- a silvopastoral initiative; and
- strengthen national climate and early warning information systems.

Path 5: Consider the multifunctionality of silvopastoral systems to enhance the integrated management

Silvopastoral management is based on agroecological principles and agroforestry techniques integrating agriculture, forestry and livestock production, generating diverse and productive landscapes. The conceptual framework (Figure 3) devised by this technical paper focuses on management as the main contribution of silvopastoralism to improved production, land degradation neutrality and ecosystem restoration. This paper has demonstrated that fine-tuned management systems lead to strengthening the multifunctionality of silvopastoral systems with the best results.

Good silvopastoral management simultaneously integrates the different elements of the system and their interactions under the decision-making skills of their managers. Silvopastoral management is traditionally a collective task, even within single-owned lands (Pinto-Correia *et al.*, 2021) meaning that community-based instruments are necessary to guarantee its proper functioning.

There are two important elements to consider when discussing the management of a silvopastoralist system. First is the efficiency of grazing, meaning the capacity of silvopastoralism to obtain from the environment and transform raw vegetal fibres into high-quality products. This is an important part of dryland management as it makes a big difference to productivity. Management plans should focus on boosting grazing efficiency by combining different tools, including optimizing schedules, stocks, herd size, species and breeds on the livestock side; and

combining trees, shrubs and grasses, adjusting shapes and edges, or enriching pastures with nitrogenous-fixing plants on the forestry side. The second factor is the management of tree cover, adjusting the different vegetation layers and combining shade and light by controlling canopies and tree densities. Cover management is not only about a balance between sunlight (more production in good conditions) and tree shade (more protection in harsh conditions and additional food) but a complex trade-off affecting the whole system. Skills and experience are instrumental to make good decisions over both factors and have a great influence on the performance of the system and the services provided.

On the other hand, general recommendations point to incorporating silvopastoralism as a land management tool, profiting from its integrative forestry-livestock approach and some of its main properties, listed in the previous paragraph. Under this perspective, silvopastoralism could be adopted as a mechanism to maintain and manage public and private lands s, complementing other agricultural and livestock farming initiatives and the services sector, especially under a circular economy perspective.

In summary, facilitating the transition to enhance the multifunctionality of silvopastoral systems requires several management-linked measures:

- diversify production by introducing forest and rangeland alternative productions in a sustainable management system;
- diversify silvopastoral production by introducing different livestock species and breeds (not only ruminants but also poultry and beehives), adapted to extensive production and local conditions;
- manage silvopastoral areas to generate open savannah-like and mosaic lands with a diversity of fodder resources. For example, diversify and extend in time the available feed resources for grazing animals in silvopastoral systems;
- promote livestock mobility and transhumance in silvopastoral land management as a way to grant regeneration and pasture resting periods;
- promote rotational grazing mechanisms granting adequate grazing livestock stocking rates at each moment and sufficient resting periods for each patch of land managed. For example, avoid free-range all-year-around grazing in forest lands by providing planned alternatives for the people depending on those resources;
- promote soil and water conservation structures aiming to reduce soil erosion and improve the water cycle introduce community-led silvopastoral management practices, reducing external dependence and enhancing the benefits for the whole community;
- use a silvopastoral approach to facilitate adaptation of grazing livestock to climate change, while enhancing the role of forest landscapes in mitigation; and
- mobilize seed investments to support silvopastoral initiatives and reduce the stress on forest and tree biodiversity.

Path 6: Incentivize and diversify value chains of silvopastoral and forest products

Silvopastoralism can contribute to alleviating poverty by generating a diversified, self-sufficient and sustainable production that benefits the whole community. Silvopastoralism is often the only way to combine the provision of protein-rich high-nutrient quality food with additional resources, such as fuelwood or construction materials, in impoverished environments.

While many of the previous recommendations aim to increase the positive impact of silvopastoralism in local communities in general, it is important to specifically address this issue here. The system's performance will ultimately rely on the interest, engagement and leadership of local communities, so the benefits for them should be neatly established.

Value chains for silvopastoral products must be adapted to the production capacity and size of the potential market, as well as linking production and transformation to maximize the revenues for producers. Those value chains then need to be shortened and simplified, so benefits are locally gathered and reinvested.

Finally, a changing world can provide new opportunities for production, which could be seized by local communities. However, silvopastoralists often do not have the time or expertise to handle product marketing and trade. Several of the case studies in the paper promote the use of external help or collective initiatives for producing, transforming, distributing and marketing their products.

In summary, facilitating the transition to incentivize the diversification of silvopastoral value chains requires the following:

- grant access of local participants in silvopastoral initiatives to the benefits produced, increasing their impact on food security, self-sufficiency and livelihoods;
- promote alternative value chains for silvopastoral products. for example, develop small transformation collective facilities for dairy or harvested wild products to engage households, small producers, marginalized collectives;
- develop logistics and support for differentiated value chains;
- seek opportunities in new markets and urban environments while retaining multifunctional and balanced production;
- help silvopastoral cooperatives and collective enterprises to transform, distribute and market their productions; and
- promote circular economy-based production.

Path 7: Strengthen the monitoring and information systems

This path includes recommendations to improve ecosystem health, achieve land degradation neutrality, or restore the dryland ecosystems using silvopastoral tools. An important consideration when discussing forest restoration is that the paths forward do not necessarily refer to continuously tree-covered lands. Instead, savannahs and savannah-like landscapes, open forests, woody rangelands, lands with scattered trees and other silvopastoral and agrosilvopastoral lands can act as fully functional forests in dryland, especially under flexible and adaptive

silvopastoral management systems. A single tree, a small grove, a tree line, a bunch of shrubs, or a patch of land covered by separated trees can comply with part of what is expected of a forest in terms of ecological functions and services, protecting the land they occupy and improving the livelihoods of their keepers. Adapting the collective imagery for forests unleashes a whole set of opportunities for restoring drylands using the monitoring tools that silvopastoralist culture stores in its knowledge heritage.

Monitoring efforts are recommended throughout implementation and after the restoration and rehabilitation efforts have ended, to allow for adaptive management. Silvopastoral land degradation and management information need to be obtained from different resources at the country level. For instance, country-validated national datasets prepared for land degradation monitoring and reporting in the context of the UNCCD national reporting process and SDG Indicator 15.3.1 reporting; country national communications including the annual GHG inventory submission to the UNFCCC and the national reporting to biodiversity-related conventions. Examples of available tools include SEPAL, Trends, Earth and others like the good practice of FAO Global Forest Resources Assessment (FRA), which is a well-established country-driven process of collection, compilation and reporting on global forest resources, their management and uses.

The implementation of sound information and monitoring system demands some enabling conditions that need to be addressed at different scales. This initially consists in identifying real information needs, followed by setting up relevant methodologies, protocols, procedures and logical frameworks for monitoring (including criteria and indicators in the way used in this paper). There is also a need for a systematic database of dryland, degraded lands and or silvopastoral lands ranging from regional to national and local scales. These conditions should allow to implement a silvopastoral information system for all scales: regional, national, local, and so on, with different resources and tools assigned. In summary, strengthening monitoring and information system will support the transition towards the best results of the recommendations developed in the previous paths.

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Annex 1: Glossary

Term	Definition
Acculturation	assimilation to a different culture, typically the dominant one
Afforestation	the action of planting trees on an area of land in order to make a forest, especially on land not previously forested
Agdal	a traditional land management practice originally from North Africa, that governs access to communal pastoral lands and resources, mainly by fixing opening and closing dates
Agricultural uses	the different land uses linked to agricultural production: crops, pastures, orchards, groves, etc.
Agroecology	a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems
Agroforestry	the interaction of agriculture and trees, including the agricultural use of trees. This includes trees on farms and in agricultural landscapes, farming in forests and along forest margins, tree-crop production, silvopastoralism and agrosilvopastoralism (Grebner and Boston, 2022)
Agrosilvopastoralism	a form of agroforestry that integrates trees with grazing animal production and crops, including woody crops and/or herbaceous crops (Pardini and Nori, 2011)
Breeding	controlled selection and reproduction of domestic animals in order to improve desirable qualities
Browsing	a type of herbivory in which an animal feeds on leaves, sprouts, or fruits of woody plants such as shrubs
Clearing	removing trees and other woody vegetation from an area in a wood or forest. Also a forest area from which trees and bushes have been removed
Community-based management	a bottom-up approach of organization, often externally facilitated, which aims for local stakeholder participation in the planning, research, development, management and policymaking for a community as a whole
Coppicing/Coppice selection	a silvicultural tool consisting of cut back trees or shrubs to ground level periodically to stimulate growth. The regrowth can be selected to facilitate forest regeneration
Deforestation	the cutting down of trees in a large area, or the destruction of forests by people
Desertification	a process of land degradation driving productive lands into desert, typically by drought, climate change, unsustainable agriculture or deforestation
Drylands	zones where precipitation is balanced by evapotranspiration. UNEP defines drylands as tropical and temperate areas with an aridity index of less than 0.65
Extensive livestock production	the different livestock farming systems using the natural resources of a territory, with a low use of external inputs and mainly by outdoor grazing
Forest grazing	the use of any forest or tree plantation as a direct source of livestock feed; it has been traditionally considered just as an historical use but more recently as a land management tool and part of multifunctional SPS (Varga, 2017)
Grassland	a large area of land covered with grass

Term	Definition
Grassland-based livestock system	the different livestock farming systems using the natural resources of the territory, with a low use of external inputs and mainly by outdoor grazing
Grazing lands	land where farm animals feed on grass
Grazing livestock systems (GLS)	the different livestock farming systems using grasslands as main source of feed including harvested forages, pasture, and range
Hedgerows	a line of different types of bushes and small trees growing very close together, especially between fields or along the sides of roads in the countryside
Hima	a reserved pasture, originally from the Near East, where trees and grazing lands are protected from indiscriminate harvest on a temporary or permanent basis
Holistic grazing management	a planned rotational grazing model, established originally by Allan Savory over 40 years ago, that applies a global perspective to water cycle, mineral cycles, energy flow and community dynamics
Intensive silvopastoral system	a SPS that combines high-density cultivation of fodder shrubs with improved grasses, densified tree species or palms and grazing livestock (Grebner and Boston, 2022)
Intensification	the fact of becoming greater, more serious, or more extreme, or of making something do this
Land degradation	the deterioration or loss of the productive capacity of the soils for present and future
Modern silvopastoral system	(also delimited SPS, improved SPS or designed SPS,) is a design-based purposeful combination of trees, shrubs and grazing livestock in a single agricultural unit or SPS
Multifunctionality	a property of agricultural or agroforestry systems able to generate different productions and services at the same time
Native species	a species whose presence in a given location is a result of natural evolution processes during history
Non-timber forest products (NTFP)	any product or service other than timber that is produced in forests, including fruits, nuts, vegetables, fish and game, herbs and medicinal plants, flowers, resins, essences, barks, etc
Open forest	vegetal communities with a discontinuous tree layer covering between 10 and 40 percent of the surface
Pastoralism	extensive livestock production in the rangelands
Prescribed burning/fires	a form of land management in which fire is intentionally applied to vegetation with different objectives such as controlling dry flammable vegetation, induce the growth of pastures, generate new habitats, etc
Presumed drylands	areas with aridity indices equal to or above the drylands definition (>=,65) but exhibiting seasonal water shortages and similar challenges as 'official' drylands
Rangeland	(also range) lands, predominantly populated by grasses, grass-like plants, forbs or shrubs, and often with trees, that are grazed or have the potential to be grazed by livestock and wildlife
Reforestation	the act of planting trees in an area where there used to be a forest
Rewilding	restore an area of land to its natural uncultivated state (used especially with reference to the reintroduction of species of wild animal that have been driven out or exterminated)
Rotational grazing	a grazing system based on shifting of livestock to different pasture or range units in a planned sequence, to improve production while allowing the recovery and growth of the pasture plants after grazing
Seedling	a very young plant that has grown from a seed
Semiextensive livestock production	the different livestock farming systems combining extensive production with intensive stages or feed supplementation from concentrates

Term	Definition
Shelterwood cutting	removing a significant portion of the mature trees in one cut from an area, with the remaining trees providing a source of seed and shelter for a new stand of trees
Shredding forest residues/Chipping	processing forest residues and materials by reducing them to small pieces for fuel or soil improvers
Shrub encroachment	phenomenon characterized by the increase in density of woody plants, mainly bushes and shrubs, at the expense of the herbaceous layer
Silvopastoral system (SPS)	a silvopastoral agricultural production unit that integrates woody vegetation (trees and/or shrubs) with grazing animal production (Peri, Dube, and Costa Varella, 2016). For the purpose of this report, any production unit that integrates woody vegetation and grazing livestock is considered a SPS
Silvopastoralism	a form of agroforestry that combines grazing livestock with forestry, benefiting from the ecological relationships between animals and woody plants (Plieninger and Huntsinger, 2018; Mosquera-Losada, Rigueiro and McAdam, 2005)
Small ruminants	small-sized ruminant livestock including sheep and goats
Social-ecological systems	a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner
Stand density	a quantitative measure of tree cover on an area, measured usually through an index based on the number of trees per unit area and diameter at breast height
Target grazing	a grazing regime consistent in the application of a specific set of livestock at a determined moment, duration, and intensity to accomplish defined vegetation or landscape goals
Terrestrial animal source foods (TASF)	to all food products derived from livestock production systems of any scale and from wild terrestrial animals
Thinning	partial removal of trees to reducing competition, accelerate growth of remaining trees or reduce flammable vegetation, among other purposes
Timber	wood prepared for use in building and carpentry, also the trees that are grown to produce wood for those uses
Transhumance	practice consisting of moving livestock from one grazing ground to another in a seasonal cycle to optimize grazing
Urbanization	the concentration of human populations into discrete areas, also the transformation of land uses for residential, commercial, industrial and transportation purposes driven by this transformation
Windbreakers	a tree or shrub shield planted or arranged to protect something from the wind

Annex 2: Contribution of agriculture and forest to GDP and livestock production index in countries with drylands

Country	GDP in billions (USD) 2020	Share of agriculture GDP as percent in overall GDP 2019	Share of forest/ or trees GDP in overall GDP in 2019	Livestock production index points 2019
Afghanistan	20.12	25.77	0.4	105.0
Algeria	145.01	12.34	0.2	93.4
Angola	58.38	6.66	0.4	101.6
Argentina	389.29	5.11	0.1	108.2
Armenia	12.64	11.53	0.2	100.8
Australia	1 327.84	2.12	0.2	96.3
Azerbaijan	42.61	5.70	0.0	107.2
Bahamas	9.91	0.52	0.0	99.0
Bangladesh	351.24	12.68	0.1	105.2
Bolivia (Plurinational State of)	36.60	12.22	0.4	111.8
Botswana	15.06	2.10	0.2	96.5
Brazil	1 444.73	4.40	0.6	106.5
Burkina Faso	17.93	18.38	4.0	100.9
Burundi	2.84	28.90	9.2	104.4
Canada	1 645.42	1.70 (2018)	0.1	106.5
Cabo Verde	1.70	4.63	0.3	93.7
Central African Republic	2.38	31.49	8.3	106.2
Chad	10.83	42.59	3.3	115.7
Chile	252.94	3.61	0.7	97.7
China	13 021.05	7.14	0.1	101.1
Colombia	271.44	6.39	0.1	104.1
Comoros	1.24	35.69	1.2	100.4
Cyprus	24.61	1.81	0.0	108.9
Democratic Republic of Congo	48.72	19.97	7.0	103.8
Djibouti	3.38	1.27	0.3	132.2
Dominican Republic	78.84	5.23	0.0	102.2
Ecuador	98.81	8.80	0.3	94.9

Country	GDP in billions (USD) 2020	Share of agriculture GDP as percent in overall GDP 2019	Share of forest/ or trees GDP in overall GDP in 2019	Livestock production index points 2019
Egypt	365.25	11.05	0.1	90.6
Eritrea	1.98	24	2.3	99.2
Eswatini	3.973	8.77	2.9	
Ethiopia	92.61	33.52	4.4	104.3
Gambia	1.87	20.02	2.3	99.0
Ghana	68.53	17.32	2.9	102.5
Guinea-Bissau	1.43	30.40	8.6	104.4
Haiti	14.51	19.49	0.5	101.5
India	2 660.25	16.68	0.2	116.8
Iran (Islamic Republic of)	203.47	12.18	0.0	106.6
Iraq	166.76	3.75	0.0	88.8
Israel	407.10	1.13	0.0	99.4
Jamaica	13.81	7.02	0.1	110.3
Jordan	43.70	4.91	0.0	03.6
Kazakhstan	171.08	4.47	0.0	111.4
Kenya	95.41	21.17	1.0	109.7
Kuwait	105.96	0.38	0.0	147.3
Kyrgyzstan	7.74	11.67	0.0	106.0
Lebanon	31.74	3.08	0.0	97.7
Libya	25.42	1.85 (2008)	0.1	105.9
Madagascar	13.06	22.96	3.7	102.0
Malawi	12.18	23.00	5.1	141.5
Mali	17.47	37.31	1.8	128.3
Mauritania	7.91	21.68	1.0	103.7
Mexico	1 073.92	3.39	0.1	108.6
Mongolia	13.31	11.56	0.1	154.7
Morocco	114.73	12.15	0.1	106.0
Namibia	10.62	7.11	0.5	96.6
Nepal	33.66	21.58	0.5	114.4
Niger	13.74	36.91	3.8	111.4
Nigeria	432.29	21.91	0.8	100.6
Oman	73.97	1.99	0.0	135.0
Pakistan	262.61	21.97	0.1	111.1
Papua New Guinea	24.67	18.98	1.8	103.1
Paraguay	35.67	10.00	1.2	103.9
Peru	202.01	6.75	0.1	111.3
Qatar	144.41	0.26	0.0	108.0
Rwanda	10.33	23.54	3.2	97.1
Saudi Arabia	700.12	2.23	0.0	109.6
Senegal	24.64	14.99	1.3	104.3

Country	GDP in billions (USD) 2020	Share of agriculture GDP as percent in overall GDP 2019	Share of forest/ or trees GDP in overall GDP in 2019	Livestock production index points 2019
Seychelles	1.06	2.24	0.1	104.3
Somalia	6.97	75	13.5	96.2
South Africa	335.44	1.96	0.6	97.6
South Sudan	11.99 (2015)	20.36 (2020)	2.6	
Spain	1 281.48	2.59	0.0	111.1
Sri Lanka	80.68	7.54	0.1	117.5
Sudan	21.33	20.16	2.2	104.1
Swaziland	3.97	8.54	NA	100.4
Syrian Arab Republic	22.77 (2019)	39.77	0.0	97.9
Tajikistan	8.19	20.87	0.9	108.9
Tunisia	41.62	9.64	0.3	100.3
Türkiye	719.95	6.40	0.1	103.3
UAE	358.87	0.75	0.0	119.0
Uganda	37.60	22.95	6.1	101.9
United Republic of Tanzania	62.41	26.55	1.8	97.6
Uzbekistan	59.93	24.61	0.0	110.2
Venezuela (Bolivarian Republic of)	462.35 (2014)	NA	0.1	80.6
Yemen	21.60 (2018)	5.00	0.1	98.6
Zambia	18.11	2.86	4.6	108.9
Zimbabwe	18.05	10.14	1.6	103.9

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FAO FORESTRY PAPER

Grazing with trees

Trees in dryland forests and wooded areas provide key ecosystem services such as animal feed, timber, fruits and, regulation of soil and water cycles. Equally, the presence of livestock in dryland woody areas can also play an important role in the local ecosystem; not only are they a source of income for local communities, but they also help vegetation and mobilise stored biomass. When both of these ecosystem elements are wisely combined – livestock and trees – it creates an integrated agricultural system that can boost the local ecosystem, representing a welcome agro-ecological transition in livestock farming. The 'Grazing with Trees' report gives a thorough assessment of the positive role that optimized extensive grazing livestock farming can play in the management and restoration of drylands' forests and lands with trees. It assesses and provides sound evidence on the benefits of applying an integrated landscape approach and utilizing farmers and pastoralists' knowledge to halt desertification, increase resilience, and enhance food security under the actual changing scenario. The report confirms the importance of agroforestry as a primary pathway for forest restoration in dryland areas as recommended by FAO's State of Forests 2022, and its recommendations encourage landscape planners and decision makers to consider livestock as allies, carefully restore tree cover and accelerate action to promote healthy ecosystems.

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